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ROGER BACON PRESENTING A BOOK, PERHAPS TO THE CHANCELLOR OF PARIS

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EARLY SCIENCE IN OXFORD

BY

R. T. GUNTHER

VOL. II

ASTRONOMY

OXFORD
PRINTED FOR THE OXFORD HISTORICAL SOCIETY
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DEDICATION

TO

LEWIS EVANS, F.S.A.

WHO HAS GENEROUSLY OFFERED
HIS COLLECTION OF SCIENTIFIC INSTRUMENTS
TO THE UNIVERSITY OF OXFORD

PREFACE

In presenting this account of astronomical instruments with notes on certain phases of the progress of the Science in a single University, we have consciously adopted an arbitrary basis for the selection of the matter to be included. We have in our collections in Oxford specimens that illustrate both the educational methods and research carried on by schools and individuals within our walls, as well as a variety of miscellanea that have survived amongst us, some for their scientific value, some for artistic value and excellence of workmanship, some for historical or sentimental interest. Many of these instruments, though having no special relation to Oxford, are most valuable as indicating the advance of astronomy elsewhere.

To the collections of astronomical instruments that have been in Oxford for centuries, the University has now the opportunity of adding the superb collection of portable instruments that have been most carefully selected by Mr. Lewis Evans during the past thirty years, a collection which more than any other in private hands illustrates the skill of the early scientific instrument maker at his best, in all countries and in all ages. Moreover, owing to the rarity of examples of the work of many of the makers, it is a collection which is beyond the power of any one to bring together again. It is the earnest desire of every man of science in Oxford that, in accordance with Mr. Evans's wish, his instruments should form a nucleus round which kindred objects might be gathered as a Science Museum in Oxford, the special feature of which should be to illustrate

that part which Oxford herself has played in the progress of the Natural Sciences.

It would seem appropriate to have a Museum dedicated to studies which after all are indigenous in this, the oldest of our Universities. The allocation of the building which was our oldest Science Museum would not be unreasonable for this purpose: we are already very amply provided with two museums for exotic barbaric arts, and the history of the scientific instruments, which have made modern civilization possible, would seem to be no less worthy of study and endowment.

To the list of those friends and institutions to whom acknowledgement of services has already been made, I gladly add the Delegates of the University Press and Magdalen College who have generously given subsidies of £100 to the cost of illustrating the scientific possessions of other Colleges and Institutions. The technical assistance of other friendly helpers is acknowledged in the text.

No town can boast a richer abundance of historic scientific instruments than Oxford: we pray that the unlocking of the cupboards in which they have defied the centuries may not lead to their destruction.

R. T. GUNTHER.

MAGDALEN COLLEGE
1 *July*, 1923.

[*The present volume is one of a certain number printed off, by arrangement with the author, for issue to members of the Oxford Historical Society.*]

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JOHN STOEFFLER, 1452–1531

Author of Elucidatio fabricae ususque Astrolabii, *who has transmitted his interest in the Astrolabe through twelve generations to one of his descendants, the author.*

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EARLY SCIENCE IN OXFORD

VOL. II.—ASTRONOMY

INTRODUCTORY

THE collections of instruments which are in the possession of individual Colleges and of the University illustrate several of the most important stages in the progress of Astronomical Science. It is true that Oxford cannot boast of having produced astronomers of the fame of an Hipparchus or a Tycho, a Galileo or a Herschel, but by strange good fortune there are stored in out-of-the-way corners astronomical instruments, forming in the aggregate a typically English series that is unequalled in Britain. At no other centre in this country can the astronomy of periods so widely separated be studied alongside contemporary instruments in the very place in which these were used; in fact the astronomical methods of at least three periods are better, or more fully, illustrated in Oxford than by any collection of instruments elsewhere.

No instrument definitely associated with the name of ROGER BACON or of his time has survived, even his observatory was wantonly destroyed about 1770. The Oxford collections begin with astrolabes and quadrants dating from the middle of the fourteenth century. To the first of our three periods we refer these older instruments which supply positive evidence respecting the methods, the accuracy, and the limitations of the School that we may call the MERTON SCHOOL of English Astronomy. On all these points the instruments speak more definitely than a printed page. They belong to the period when astronomy was regarded as directly influencing the bodily and spiritual welfare of man; when the attractive theory of the direct influence of heavenly bodies on the human frame and the possible prediction of future events was being put to the test by

accurate observation. The ocean is drawn by the sun and moon, why should not men also be influenced by the stars in their courses? or at any rate such mortals as have 'mercurial', 'jovial', or 'saturnine' temperaments or have been born 'under a lucky star'? This research was of absorbing interest. It led to a great improvement in the best method of studying Science, that of the stringent necessity of scrupulously accurate observation, and the keeping of records as accurate: it is only by this method that man has learnt and is still learning how far and in what spheres he may venture to deduce consequences with success. In those early days results were not achieved as rapidly as at the present time.

The home-made instruments of the Merton School were doubtless used, or partly used, for astrology; but this does not detract from, it rather adds to, their human interest. Two of them were apparently planned for the use of the members of the College, and one has the additional glamour of being associated with the name of our great astronomer-poet Chaucer, who was not a believer in astrology.

Next, we have in the Library of Christ Church a representative collection of instruments of English manufacture of the second period, which I venture to think is absolutely unique. It is of surpassing interest because these instruments, made of the best brass and glass work obtainable at the end of the sixteenth century, by well-known English instrument makers, such as Sutton, Marshall, and Rowley, for a wealthy patron, the Earl of Orrery, have been kept together in a cupboard in their original state for some two hundred years. The Orrery collection represents to us more completely than any other the instrumental equipment of the amateur astronomer of the beginning of the eighteenth century; than which the scientific astronomer of the time had no better, and that which he had has been lost.

That no one may think too much stress is being laid on the value of this collection, it may be pointed out that although they may have been richer, other collections have been dispersed, generally by their custodians.

The collection of the Royal Society, once so comprehensive, can now boast of very few of its earlier treasures; those that were extant a few years back are enumerated in this catalogue. Even in 1720, and therefore some twenty years later than the date of the greater part of Lord Orrery's apparatus, the Royal Observatory at Greenwich, incredible as it may seem, was absolutely without instruments of any kind. Only within the last few years has the State begun to realize the immense educational importance of early scientific instruments; and with great difficulty the older types of apparatus are gradually being brought together from any and every source for the National Science Collection at South Kensington.

It is thus that Oxford, more by good luck than by design, is the possessor of a unique if small cabinet of philosophical apparatus untouched and long unknown, so that it escaped the adaptive ingenuity of the younger physicists, who with genuine enthusiasm for the advance of their science, have unnecessarily destroyed or dispersed so many of the records of the work of their predecessors. In the Orrery collection we find among other apparatus examples of the many-draw telescopes of the kind used in the time of Flamsteed or Hevelius, the beautiful educational models of the Solar system according to different theories, and an early copy of the Orrery.

Representing the third period we have almost intact the magnificent equipment provided by the Trustees of Dr. Radcliffe for the Observatory that bears his name. These instruments were needed for the laborious survey of the heavens by the accurate and separate determination of the position of every individual star, which was the only method before the photographic telescope extended the work.

The Radcliffe instruments were the work of a maker of rare genius and industry. The fame of Bird had spread even to Russia, and his services were competed for by the Observatories of Europe. His *chefs-d'œuvre* were justly regarded as unrivalled, even by English instrument makers who were then regarded as the best in the world.

By the acquisition of Bird's quadrants and other instruments, Oxford was in advance of Greenwich, or of any other observatory; but unhappily it was long before they were put to a worthy use, for no observations were published at Oxford before 1840. These matchless instruments, though corroded with age, are still in their original positions.

The preservation of these few relics of the past is an easy matter, and we hope that it will be always considered a duty. A larger work is the carrying back of astronomical tables into the earlier centuries with fresh working out of the observations of the old astronomers to the benefit of chronology.

Our enumeration of the Oxford astronomical instruments ceases with the close of the eighteenth century, for the instruments acquired later are almost all of modern type.

ASTRONOMER OF THE XII/TH CENTURY.
MS. Bodl. S. C. 2144.

EARLY ASTRONOMICAL INSTRUMENTS

In any survey of scientific instruments priority should be given to those used in the pursuit of astronomy, for they to a greater degree than any other appliances have retained forms handed down from a high antiquity, and many of the fundamental astronomical problems of astronomy are being solved to-day by instruments which for centuries have undergone no material alteration. Yet the history of the evolution of astronomical instruments is that of all scientific research, and shows a continual process of development from the simple to the complex, from the general to the special: in their expansion and improvement they follow on the ever-widening, combining, and co-ordinating activity of the mind of man.

In the early days of the science observatory and instrument and, in some cases, instrument and observer were one and the same. The Tower of Belus of the Chaldeans and the great golden Circle of Osymandyas in Egypt were both observatory and instrument. The gnomon, the introduction of which from the East is attributed to Anaximander, is an instrument fixed in the meridian; it is an integral part of the sundial, and every sundial is an astronomical instrument.

These primitive conditions are still to be found among the backward races. The Fellahin Arabs usually get the time by measuring their shadows in lengths of their naked feet. In the Dakla oasis a much more elaborate method is still in use. A line running north and south is first scratched on a level place on the ground. One man stands at the south end of this line with his back to the sun, and places the bottom joint of his forefinger against the tip of his nose with the finger pointing skyward; the shadow of his finger then appears in the central line of the shadow thrown on the ground by his head. A second man marks this point on the ground where the shadow of his finger falls, and from that point draws a perpendicular to the north and south line. The first man then measures the length

of this perpendicular in terms of his naked foot-length, and thus deduces the time of day.[1] It was the old Greek plan. Aristophanes (430 B.C.) defines the time of day by the shadow length of a man; and Theodosius (*c.* A.D. 100) prescribed the following procedure: 'To find the time you must measure your own shadow by moving forward foot before foot to the end of the shadow of your head.' In these cases the observer and the instrument are one. As the study of astronomy gradually outstripped the early and simple processes and an increasing number of mechanical requisites became necessary, there arose a tendency to place the observatory, as a building, in a different category to the instruments it contained.

In any classification of instruments it is not always easy to draw a hard-and-fast line between fixed and portable, or between observatory and field instruments, but we trust that the grouping we have adopted in this catalogue may be sufficiently convenient to counterbalance a lack of strictly logical arrangement.

The origin of instrumental astronomy is lost to us, but some of the early instruments were of wellnigh indestructible material, and of such a size that they still stand as monuments to the scientific methods of settled peoples whose names are unrecorded. Rude stone circles and orientation stones of the prehistoric races of Europe and other continents were orientated with considerable precision and were probably used as observatories for the determination of the length of the year and for the return of the seasons, knowledge indispensable alike to the successful pursuit of husbandry and to the civil and religious life of a community.

Stone Circles.

The North Oxfordshire stone circle at Rollright which has been referred to the latest period of the British Bronze Age, or about the third century B.C., may have served as one of these observatories. The bearing of an outlying menhir, called the Kingstone, from the middle of the Rollright circle is strikingly similar to the bearings of certain salient features from

[1] King, *Geogr. Journal*, Nov. 1917.

Long Meg in Cumberland and from the Stripple Stones in Cornwall, viz. N. 27° E. The astronomical orientation of several of the stones of Stonehenge, suggested as long ago as 1771 by Dr. John Smith in his *Choir Gawr, the Grand Orrery of the Ancient Druids*, astronomically explained, has received striking con-

THE KINGSTONE.

ROLLRIGHT STONES.

firmation from the work of Norman Lockyer in the present century.[1]

By means of a stone circle the position of heavenly bodies at their rising and setting could be easily noted in relation to particular stones. Possibly the angular intervals between the stones gave man his first idea of hours. Our arbitrary division of the day and night into twenty-four hours may have come to us originally from a stone circle in some prehistoric metropolis, which became a type. Or again, the early division of the stars on the ecliptic into the twelve signs of the

[1] *Nature*, 1905. The proportions of various measures of the circle have been carefully examined by my friend Mr. E. M. Nelson, and were printed in Gunther's *Oxford Country*, p. 240.

zodiac may have provided the starting-point. Later need for greater precision has increased the division of the zodiac circle from the rough-and-ready twelve or twenty-four to 360 divisions. This division of the zodiac into 360 degrees is attributed to Hypsicles in the second century B.C., and it was about 150 B.C. that this division was transferred to the circles of instruments by Hipparchus, whose skill in the devising and use of instruments led him to become the greatest astronomer of antiquity. Each degree modern astronomers habitually subdivide $60 \times 60 \times 5$ times into 18,000 equal parts, so that the modern astronomer's zodiac-circle is subdivided in practice by micrometric methods into 6,480,000 equal parts.

The most perfect of the architectural instruments which have come down to us from prehistoric times are the great orientated temples and pyramids so accurately placed that they form a record, and the only one, of the astronomical knowledge of their builders.

As relatively modern examples of instruments of the architectural type we may cite the huge edifices constructed about 200 years ago under the direction of Jai Singh at Delhi (1724), Mathura, Ujjain, Jaipur (1734), and Benares (1737)[1], which were built to correct—a task which was not fulfilled—the Hindu calendar by means of astronomical observation. They were copies of Ulugh Beg's instruments at Samarkand (*c.* 1430).

A considerable advance in early science was made by the invention of the **gnomon.** Observers must very early have discovered the convenience of noting the position of the sun by the position of the shadow rather than by direct observation, but the advantage of using the shadow of a stick parallel to the axis of the earth was a step forward which it may have taken many generations to make.

We may therefore define the early age of astronomy as the age of *Architectural Instruments* at first rudely constructed of wood or stone, and often of cyclopean size; the instruments consisting of orientated azimuth circles, and later of fixed gnomons and spherical dials, instrument and observatory being one.

[1] G. R. Kaye, *Astronomical Observatories of Jai Singh.* Calcutta, 1918.

Early Greek Instruments

The Staff of Archimedes.

One of the oldest of the early Greek portable instruments was that called the Staff of Archimedes (287–212 B.C.), which may even have been known to Aristotle (384–322 B.C.) and in after-years became an instrument of great importance for navigation.

Archimedes applied a cylinder to a staff and used it to measure the diameter of the sun—by holding one end of the staff near the eye, and then moving the cylinder until the sun was quite covered by it. The distance of the cylinder from the eye, which was easy to measure, gave the radius, the diameter of the disk the sine of the angle of the apparent diameter of the sun. From it may have been evolved the *Regula Hipparchi.*

Next in order of invention were the Diopter and the Arachne.

The Diopter.

To judge from Ptolemy's description, the diopter of Hipparchus was a rule with 4 bends or angles; one end carried a pinnule perforated to serve as an eyesight; the other was solid and movable on the rule. By its means Hipparchus (fl. 161–126 B.C.) was able to measure small angles, such as those subtended by the diameters of the sun and moon. It could not have been known before the time of Hipparchus, because Archimedes describes a particular method for measuring the diameter of the sun as if the problem had never been satisfactorily solved.[1] There is no mention of the existence of the diopter before Dicaearchus of Messene, a pupil of Aristotle. The instrument seems to have been familiar to the school of Eudoxus (*b.* 408 B.C.) for a line of sight, but there is no evidence that Eudoxus employed the diopter in connexion with a divided circle to measure angles. Moreover, it is highly unlikely that the diopter could have been applied to a divided circle firstly because the Greeks at this very early period

[1] *Arenarius*, cited by Paul Tannery, *Recherches sur l'histoire de l'astronomie ancienne*, *Mém. Soc. Sci. de Bordeaux*, 1893.

were not acquainted with the division of the circle into degrees—the Chaldeans themselves had only applied this division to the zodiac, and it does not appear to have been employed on circles before Hipparchus—and Eudoxus was not sufficiently familiar with the idea of measuring angles by arcs to practise the method.

And secondly because angular measures were of no use without a knowledge of trigonometry. Hipparchus solved these problems by the use of similar triangles.

The Diopter of Euclid's *Phenomena* (*c.* 300 B.C.) was used apparently to find points diametrically opposite to one another.

Eudoxus was acquainted only with the division of the zodiac into signs and fractions of a sign, and did not employ an instrument suitable for measuring angular distances.[1] Hipparchus employed degrees both for zodiac and for polar distances.

In later times the diopter in the hands of Heron of Alexandria, who is now believed to have lived after Ptolemy in the third century A.D., became a surveying instrument of value.[2]

The Arachne.

The invention of a horologium (sundial) called an *arachne* is attributed to Eudoxus by Vitruvius (ix. 9); but others have attributed the invention to Apollonius.

Eudoxus no doubt availed himself of the spherical sundial; for the first flat sundials did not come into use until the following century, when they were made by Aristarchus of Samos, who had improved the ancient type of dial represented by the Scaphé which was still in use in the time of Eratosthenes. The horologium of Eudoxus was probably a spherical sundial; but the term *arachne* implied a new complication.

Instruments of the Alexandrine School

The earliest astronomical instruments of which we have more than mere verbal tradition were those used

[1] A division of the circle into 60 parts was the custom a long time even after the time of Hipparchus. Aristarchus of Samos was only acquainted with fractions of a sign; Archimedes (*Arenarius*) only with those of the right angle.

[2] Heath, *Greek Mathematics*, ii, p. 345.

by the Alexandrine Greeks. The astronomers of Alexandria, who made extensive use of instruments for measuring angles, are generally considered to have been the first to determine the position of stars by systematic observations. Their improved instruments enabled them to settle the course of the planets and the inequalities of the motions of the sun and moon[1] with greater accuracy than had been done heretofore. The nature and efficiency of their instruments may be estimated by the observations which have been handed down by Ptolemy and the Arabian savants. The names of ARISTYLLUS and TIMOCHARIS (290 B.C.), of ARISTARCHUS of Samos (*c.* 310–230), and especially of HIPPARCHUS of Bithynia (fl. 161–126 B.C.), are well known in connexion with results consequent on the use of more precise methods. It is from the apparatus of the members of the Alexandrine School that several parts of our present-day instruments have been evolved.

Among early instruments, that have become 'historic' though not scientific, should be mentioned the well of Syene, which, being illumined right to the bottom by the rays of the sun on the day of the summer solstice, was thought to have enabled ERATOSTHENES to measure the size of the earth.[2] But a resifting of the evidence has shown its flimsy nature. Dr. Dreyer has reminded us that Eratosthenes measured his arc from a place where the gnomons of sundials cast no shadows at the summer solstice, and did not allude to a well. On the other hand Pliny mentions a shadowless well, though *not* in connexion with Eratosthenes.[3] It would be interesting to trace the scholar who joined these two

[1] The discoveries of the inequalities of the motions of the sun and moon were made by Meton and Euktemon (433 B.C.), and by Kalippus (325 B.C.) respectively (Dreyer).

[2] The result obtained has been ably criticized by Mr. E. A. Reeves. By these observations Eratosthenes would have found that the measure of the arc of the great circle between Alexandria and Syene was $\frac{1}{50}$th of a great circle, or 7° 12′. The linear distance between these two places he took to be 5,000 stadia, so multiplying the 5,000 by 50, the proportion of the arc he had measured to the whole circle, he found the circumference of the earth to be 250,000 stadia. His stadium = 516·73 feet (Dreyer).

[3] Dreyer, *The Observatory*, 1914. Syene is not exactly on the Tropic of Cancer. The lat. of Syene = 24° 5′, and the obliquity about 235 B.C. was 23° 43′·4.

statements together. We must therefore conclude that the well was not used for determining the obliquity but only for popularizing the observation. The Greek natural philosophers made use of models to demonstrate the results of their astronomical observations. The principal motions of the heavenly bodies were shown by Archimedes, a whole century before Hipparchus, with a model, the first known planetarium or Orrery.[1]

The most notable instrument of that school was, however, the **ring** of Hipparchus. With it the 'Father of Astronomy', *c.* 162 B.C., was enabled to construct the first solar tables mentioned in history; and though 'defective and even erroneous in principle', they were so durable a monument to his genius that Ptolemy three centuries afterwards did not alter them, which was a great mistake. Hipparchus determined the eccentricity and inclination of the orbit of the moon, and calculated all eclipses for 600 years to come. By comparing his own data with the observations recorded by Aristyllus and Timocharis, 130 years earlier, he was led to the discovery of the precession of the equinoxes. His catalogue of the fixed stars with latitude, longitude, and apparent magnitudes contained 850 stars, but has been lost.

There has been much flow of ink to deplore the burning of the Alexandrian library in the 4,000 baths of the city. But, like another Fellow of my College, I am inclined to doubt whether the loss is as great as has been supposed.

After the death of Hipparchus the members of the Alexandrine School contributed some improvements in the construction of astronomical measuring instruments, by means of which they must have made a vast number of observations. For it was only from a very extensive collection of numerical data that the wonderful lunar and planetary theories set forth by PTOLEMY (*c.* A.D. 139) could have been elaborated.

The work of Ptolemy, as set forth in the *Almagest*, first translated into Latin about A.D. 1230, and in his *Geography* (in Latin in 1482), held supreme sway over

[1] This planetarium was described by its inventor in a treatise called *Spheropee.*

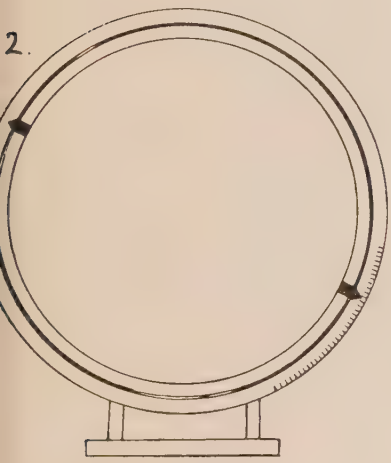
the minds of all scientific astronomers for thirteen centuries, until the time of Copernicus.

It is no part of our present plan to discuss the origin of the various Alexandrine instruments; sufficient to our purpose is the following list of instruments known to PTOLEMY; they are the precursors from which many of the Oxford instruments have been modelled.

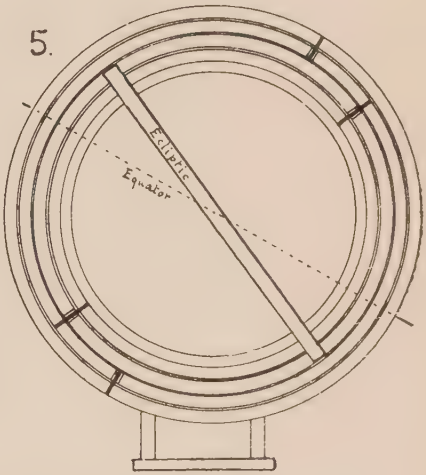
ALEXANDRINE INSTRUMENTS *c.* A.D. 140

1. Aequinoctial Armilla.

A ring of bronze fixed in the equatorial plane. The arrival of the equinoxes was noted when the shadow of



SOLSTITIAL ARMILLA.



PTOLEMY'S ASTROLABON, A. D. 139.

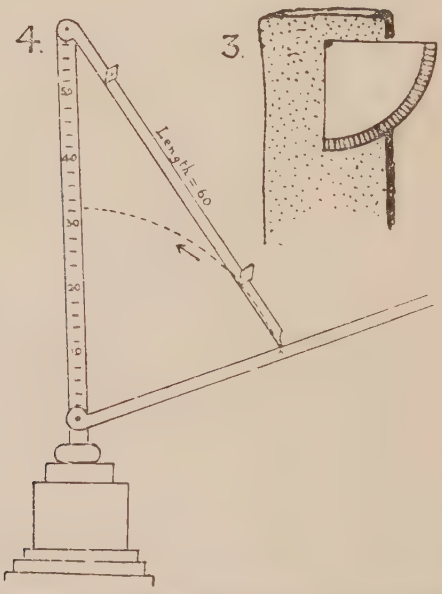
the upper half of the ring exactly covered the lower half. There was also one at Rhodes. No adjustment was possible. Similar instruments were set up in several towns, probably for purposes of civil government or general interest rather than for scientific ends. The Alexandrian ring was set up in the portico called 'Square'. An observation made with it on 21 March 146 differed by 5 hours from a corresponding observation made at Rhodes.

2. Solstitial Armilla.

A ring of about 16 in. in diameter and square in section was divided into 360 degrees on one face and was fixed upright in the meridian by means of a previously found meridional line and a plumb-line. Within the outer ring a smaller concentric ring was inserted so as to rotate within the first: it bore upon its face two projecting points, diametrically opposite, which served, the one for casting, the other for receiving the shadow of the sun, the altitude of which could thus be read in degrees on the outer ring.

3. Mural Quadrant.

One side of the quadrant was supported in the meridian against a rectangular block of stone, one radius having been plumbed vertically. The shadow

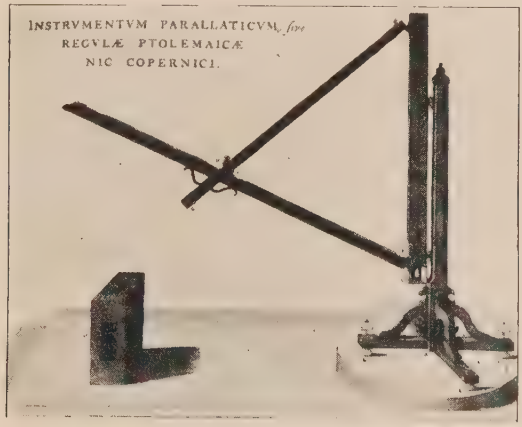


MURAL QUADRANT. PTOLEMY'S RULES OR TRIQUETRUM, A.D. 139.

cast by a point at the centre of the quadrant was received upon a plate held close to the graduated limb, and thus the altitude of the sun or moon could be measured.

4. Organon Parallactikon.

Regula Ptolemaica. Triquetrum or Parallactic Lineal. A rectangular post of some 6 ft. in height carried two arms hinged and movable in the meridian. The distance between the points of attachment of the two arms was exactly equal to the length of the upper arm and was divided into 60 equal divisions. The upper arm carried two sights for making observations; the lower arm served to read the position of the sight



TRIQUETRUM, 1584.
Tycho, Mechanica, 1602.

arm, by being hinged at the lower end of the vertical scale. Thus we have an isosceles triangle the equal sides of which = 60, and the apical angle of which can be measured by its sine.

This apparatus was intended for measuring the zenith distance of the moon. A large foresight (to take the entire disk) and a small back-sight were used.

It should be remembered that in after-years with Ptolemy's own instrument, the Triquetrum, Copernicus made those measurements with which he overthrew the Ptolemaic System, and gave us a new idea of the Universe.

5. Astrolabon.

The astrolabon organon appears to have been a universal instrument like an Armillary Sphere.

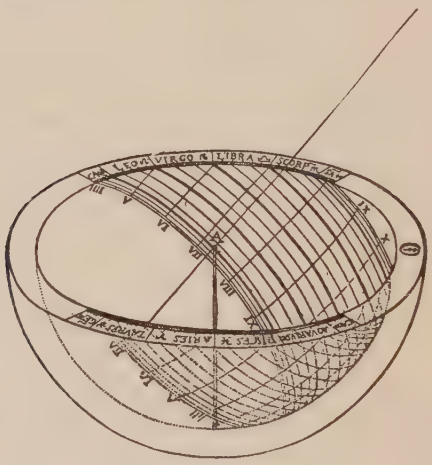
Theon states that the diameter of Ptolemy's astrolabon was 16 in. It was used to measure longitudes and latitudes. *See* p. 125.

6. Meteoroskopion.

Tannery[1] states that it had the rings of the Solstitial Armilla with other circles, up to the number of nine, and to have been a complete Armillary Sphere.

7. Scaphe.

Designed by Aristarchus of Samos in order that the readings of the position of the shadow of a gnomon might give the angular latitude without any computation. He set a gnomon at the bottom of a hemi-



THE SCAPHE.
Laussedat, Recherches sur les Instruments.

spherical bowl and drew concentric equidistant circles or semicircles on the inner surface as a scale by which the sun's altitude could be measured from the shadow of the gnomon. With such an instrument at the equi-

[1] *Anc. Astronomie*, 1893, p. 73.

noxes, the noon sun casts no shadow at the equator, hence the angular measure of the sun's shadow at any other point at this time, when the sun is on the meridian, will be the latitude.

And to this list we might add the 'Astrolabe?' that was dredged up from the bottom of the sea off Anticythera—a bronze circular instrument with cogwheels in its interior. But the description of the corroded remains of the instrument is far from complete.[1]

According to John Philopon of Alexandria, who flourished in the sixth century, quoted by Tannery, the Greeks had an Astrolabe which was as perfect as any instrument of the Arabs.

Roman Instruments

The principal authorities for our knowledge of the astronomical instruments of the Romans are the verbal descriptions of Vitruvius, a civil architect employed by Augustus, and a few examples of Roman sundials that have survived. Vitruvius undoubtedly borrowed his scientific knowledge from older Greek sources, and so the descriptions in his book on gnomonics must be regarded as part of Greek, rather than of Roman culture.

Roman Portable Sundial, *c.* A. D. 250–300.
L. Evans Collection.

A Roman portable sundial was found in excavations in Herculaneum which must have been made between 28 B.C. and A.D. 79 and probably within the last twenty

[1] Rediadis, *Der Astrolabos von Antikythera* in Svoronos, *Athener Nationalmuseum*, 1903.

Face. *Back.*

Scale of Months. *Table of Latitudes.*

RUBBINGS OF MR. EVANS'S ROMAN PORTABLE SUNDIAL.

years of that period. See p. 121. A far more important instrument is the one in the Lewis Evans collection, at present on exhibition in Oxford and figured on this page.

THE ARABIANS

For the further effective use of instruments we have to wait many hundred years and then turn to the people who, by a strange revolution in human affairs, became the protectors and cultivators of those very sciences, the records of which their ancestors had wantonly destroyed.

For five hundred years the Arabians were the focus of learning in the western world and diffused scientific studies far and wide from Bagdad to Cairo and from Cairo to Alexandria, Cordova, and Toledo.[1] And with them through the 'darkest and most slothful period of European annals' learning throve till the irruption of the Moguls in the thirteenth century began to disintegrate their civilization.

About the year 813, Almamun, who had inherited a taste for sciences from his grandfather, ascended the throne of the caliphs and became a great patron of astronomy.

[1] A wealth of Arabian biography is contained in the 'Kitab al-Fihrist' (= Book of the Record) translated into German by Suter in *Zeit. Math. Phys. Suppl.* 1892.

He constructed instruments and made accurate observations. The obliquity of the ecliptic was determined to be 23° 35′ and a degree of the meridian was measured in the plain of Sinjar. The astronomical treatise of Alfraganus belongs to this period and led to the wide diffusion of astronomical knowledge. The 'Science of the Stars' of Albategnius is still extant.

Arabian Instruments

The principal instruments in use among the Arabian astronomers during the period 1100 to 1157 have been described by Sédillot,[1] although his explanations following an Arabian original are perhaps less clear to a European than to an Oriental mind. They include

1. Mural Quadrant.

The arc, of wood strengthened by two radii at the ends, was divided to minutes on a copper band. It was firmly fixed in the meridian against a wall one side of which measured 12 ft. square. The radius of the arc is supposed to have been at least 8 ft. in length. Observations were made by means of a movable alidade.

2. Meridian Circle.

A fixed circle with a rotatable alidade with two sights was used for measuring meridional altitudes (Sédillot, p. 196).

3. Gnomon.

Meridian altitudes of the sun were also obtained from measurements of shadow (Sédillot, p. 197).

4. Armillary Sphere.

The Arabian instrument followed the lines of Ptolemy's Astrolabium with the addition of a diametric alidade. The Ptolemaic Armillary Sphere is described by Geber (Ben Aflah Hispalensis) as an *instrumentum quod nominatur habens armillas.*[2]

5. Rules of Hipparchus.

[1] *Mémoire.*
[2] *De Astronomia*, translated in Peter Apian's *Instrumentum primi mobilis*, 1534.

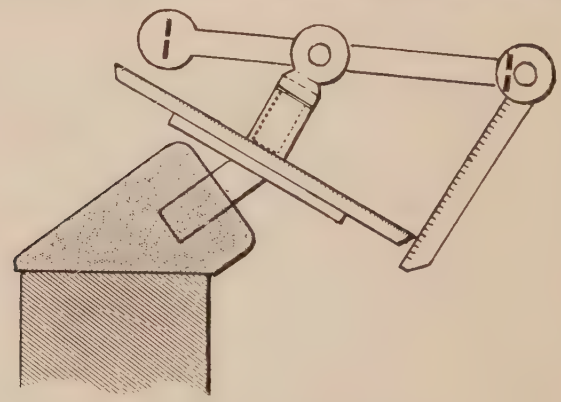
6. Planispheric Astrolabes.

In great variety. The type known as the *Saphea* was the subject of a special tractate by Arzachel.

Cf. *Libros del Saber de Astronomia del Rey D. Alfonso X de Castilla.* Madrid 1863–7.

7. Geber's Theodolite.

An *instrumentum quo scitur diversitas aspectum*[1] is stated to have been in use *c.* A.D. 1100 for measuring azimuths by the graduated limb of a circular disk and altitudes by divisions on an arm hinged to one end of an alidade fitted with sights. The principle of the construction was probably suggested by the Parallactic Lineal of Ptolemy, with the most important improvement that the



GEBER'S THEODOLITE, *c.* 1100.
After Apian, 1534.

movable alidade was given all the movements of the tube of an altazimuth. It only needed the substitution of a vertical circle of degrees for the hinged arm to give birth to a modern universal measuring instrument. This improvement was effected in the Torquetum to be presently described.

A sumptuously illustrated account of the Arabian astronomical instruments was compiled at the behest of

[1] *De Astronomia*, translated in Peter Apian's *Instrumentum primi mobilis*, 1534.

King Alfonso X of Castile. The manuscript was printed in a series of magnificent folio volumes, entitled:

Libros del Saber de Astronomia del Rey D. Alfonso X de Castilla. Madrid 1863–7.

The following titles of the chapters of Vol. III indicate the scope of the work:

1. Del orizon universal. By Arzachel dedicated to Almamun of Toledo, *c.* 1070–5.
2. De las diversas maneras de allanar la esfera. Proyeccion de la esfera en un plano.
3. De la Azafea. Composed by Arzachel in Seville, 1078–80.
4. Del año del sol.
5. De los planetarios of Abulcaçim Abnaçam, 1026.
6. Un astrolabio universal para las orbitas de los siete planetas. By Arzachel, 1081.
7. Del cuadrante. Translated before 1277.
8. Astronomical Tables and Libro del Astrolabio by Abnaçam. Beginning of the eleventh century.

The Persian Instruments

It has been asserted that Persian science dates from about the middle of the eleventh century, when the calendar was given a new form by the astronomer Omar Khayyam, but the earliest dated Persian astrolabe, the astrolabe of Ahmad and Mahmūd, the sons of Ibrahim the Astrolabist of Ispahan, is proof that the use of the instrument was understood in Persia in A.D. 984. This instrument is made for thirty-seven stars and has the latitudes and longitudes of thirty-two cities engraved within it.

Another milestone in the history of Persian science is the construction of a magnificent observatory on a large scale at Maragha by Hulagu, who put it under the superintendence of Nasir ed din (*c.* 1259). And finally the greatest of Muslim astronomers, Ulugh Beg, compiled a new star catalogue at Samarkand his capital, where he constructed a quadrant 180 ft. high, by means of which he determined the obliquity of the ecliptic to be 23° 31′ 57″ in 1437.

The Maragha Instruments[1]

1. **11-foot Mural quadrant.**

2. **Armillary sphere** of five circles, viz. the ecliptic, colure, great circle of latitude, the meridian, and small circle of latitude, were graduated down to minutes. The last mentioned was furnished with an alidade.

3. **11-foot Meridian circle** with alidade.

4. **Equatorial circle** fixed in the meridian.

5. Instrument for measuring the diameter of the sun or moon. This consisted of two sights on a bar. The objective was pierced with a comparatively large hole, and was movable along the bar over graduations.

6. **The instrument of two pillars.** A 12-foot alidade revolved round a horizontal pin. Vertically beneath this pin was another to which was fastened a graduated scale $17\frac{1}{2}$ feet long, by which the position of the alidade could be read. The instrument was therefore a modification of Ptolemy's parallactic rulers.

7. A large **azimuth circle** fixed on a pillar, traversed by two diameters directed to the four points of the compass. At the centre were fixed two vertical quadrants, furnished with alidades. Altitudes and azimuths of two stars could be taken simultaneously.

8. **Sine and azimuth instrument.** An azimuth circle, similar to the preceding, but in place of the vertical quadrants were two bars, moving in a groove, and supported by two other bars perpendicular to them.

9. Similar to No. 6, but with the bars (alidade and graduated scale) horizontal, for measuring azimuths.

Chronological List of the great Greek and Arabian Astronomers

The flow of knowledge from east to west began in the seventh century B. C. Then BEROSUS, a Babylonian, founded a school in Cos, *c.* 640 B. C., and to him succeeded

THALES of Miletus, *c.* 639–548.

PYTHAGORAS of Samos, fl. 540–510.

EUDOXUS of Cnidus, 408–355. His homocentric system was improved by Kalippus. Eudoxus' two works, the *Euoptron* and *Phaenomena*, contained a description of the

[1] Kaye, *Astronomical Observatories of Jai Singh*, Calcutta, 1918.

heavens which were practically the *Phaenomena* of Aratus who fl. 270 B. C.

ARISTYLLUS and TIMOCHARIS, *c.* 320–260 B. C., observed some star positions.

ARISTARCHUS of Samos, fl. 280–264, regarded the sun as the centre of the planetary universe, which was described by Archimedes in the *Arenarius.*

ERATOSTHENES of Cyrene, 276–196 B. C., was summoned from Athens to Alexandria to take charge of the Library. He invented or improved armillary spheres.

APOLLONIUS of Perga (fl. 250–220 B. C.) elaborated the hypothesis of deferents and epicycles.

HIPPARCHUS, fl. 161–126 B. C. His loans from Chaldean observations appear to have been numerous; but were doubtless independently verified.

PTOLEMY, *c.* A. D. 140. *Almagest.*

CALIPH AL-MAMUN built the observatory at Bagdad in A. D. 829.

TOBIT BEN KORRA, A. D. 836–901. Bagdad Observatory.

ABDARRAHMAN AL SUFI, A. D. 903–86.

ABUL WEFA, 939–98, made planetary observations, but did *not* anticipate Tycho's discovery of the moon's variation.

IBN JUNIS, *c.* 950–1008. Cairo Observatory.

AL ZARKALI or ARZACHEL, *c.* 1029–87.

NASIR ED DIN, 1201–74. Maragha Observatory, 1259.

ULUGH BEG, 1394–1449. Samarkand Observatory, 1420.

THE ANGLO-SAXONS

It is commonly stated in histories of literature and philosophy that Europe remained steeped in the ignorance and barbarity of the Dark Ages until learning was revived by the Moors in Spain.

An exception must be made in favour of a small company of Anglo-Saxons in Northumbria, the only one of the English kingdoms which 'had set aside its efforts at conquest for the pursuits of peace'. In that remote corner the Venerable BEDE, 'the father of English learning', lived for the acquisition and the imparting of true knowledge (673–735).

Never moving beyond the confines of his monastery, the monk of Yarrow obtained his materials from Greek

and Roman authors, from native chronicles, from his contemporaries, travelled monks like Wilfrid and Benedict Biscop, and from the libraries of Wearmouth and York. 'I am my own secretary, I make my own notes', he wrote, 'I don't want my boys to read a lie, or to work to no purpose after I am gone.'

Bede was essentially a scholar. From what we know of a man's capabilities it is unlikely that so industrious a reader, writer, and teacher should have had any spare time for original scientific observation. The popular writings of Isidore of Seville (*b.* 570, *d.* 636) and the works of Macrobius are channels through which much classical learning passed into mediaeval Europe. Bede drew from both. We imagine that his mastery of Greek would have enabled him to read Ptolemy in the original, or in his commentators, if any had found their way to the northern monastery. He may have seen a copy of Proclus who had written barely two centuries before. And with Greek science Bede interwove Anglo-Saxon star lore.

We might have cause for surprise that his scientific teaching should not have been apparent later among any of his 600 pupils; but there was a cogent reason for this ill success in the anarchy and bloodshed that overtook Northumbria soon after his death.

Yet disciples did not fail utterly. ALCUIN, born in 735, the year of Bede's death, was a pupil of Egbert of York, himself the pupil of Bede. Alcuin, the most distinguished scholar of the eighth century, became the confidant and adviser of Charlemagne, but his fame rests on the influence he exerted in educational, scholastic, and theological matters. In natural science he did not get as far as the Venerable Master of Yarrow, who counted upon his fingers.

In the *De Natura Rerum* Bede continually refers the phenomena of nature to natural causes. Mr. Sharon Turner observes that the then imperfect state of knowledge prevented him from discerning the true natural cause of many things, but the principle of referring the events and appearances of nature to natural laws and agencies displays a mind of sound philosophical tendency. Bede taught that thunder and lightning were due to collisions of clouds, yet such a theory directed

the mind into the right path of reasoning, though the correct series of the connected events and the operating laws had not then become known. 'He collected and taught more natural truths, with fewer errors, than any Roman book on the same subjects had accomplished.'

Of the many works which have been attributed to Bede, the Basel edition of 1563 includes the following; but several of these contain internal evidence of a later authorship. Giles's edition of 1843 'sifts the chaff from the wheat' (D.). He is inclined to accept as genuine the '*De tonitruis*; in the 4 quarters of the globe and in the 12 months of the year and on the 7 days of the week,' pp. 459–62. It is addressed to Herenfrid or Herefrid, who is mentioned by Bede in his Biographies as his particular friend. But he rejects as spurious the following:

Argumenta Lunae. This work contains a calculation for the year 936, i.e. 200 years *after* Bede's death.

Ephemeris.

De embolismo.

De mundi Constitutio. A discussion of Nebulae, Nives, Aer, Eclipses, Planetary motions, &c.

De circulis Sphaerae et Polo. With instruction for its use.

De Astrolabio. This work contains Arabic names which belong to a later period than that of Bede (see p. 199).

Pronostica temporum.

On the other hand we have not found any similarly weighty reason for rejecting the ascription to Bede of the other work *De mensura horologii*, including a section *ad meridiem inveniendum.*

The ideas expressed in this section may have been familiar to Bede. It relates to a matter upon which rests the fabric of practical astronomy: there is no more important operation in that science than the determination of the true south. Such knowledge is moreover necessary to all who would orientate their churches. The following is a translation.

To find the meridian

Describe a circle on a flat surface, and in its centre fasten absolutely straight a gnomon of such a length that its shadow projects beyond the said circle: and observe carefully, when the said shadow begins to be contained within the circumference of the circle, and mark very carefully with dots the traces of that same shadow as it shortens. Make similar observations when a second time it projects beyond the bounds of the circle—and this will happen, after the meridian has been crossed, when the declining shadow has again reached the lower points (?)[1]—and there likewise make dots.

Then bisect the interval between these dots by a straight line through the middle. On the next day, by way of testing it for the sake of the proof, carefully note when the shadow of the gnomon covers the aforesaid line, and then have no doubt that this is the meridian.

And that the observation may be made with yet greater precautions, take a carefully smoothed stone slab, and set it in a secret place suitable for this work. When you have done this, don't cease in poising the slab to continue balancing with exactness and care, until water that has been poured upon it, either lies evenly over it, or flows off the circle on all sides equally.

This method of finding the meridian also appeared in Chaucer's *Astrolabe*, ch. 38, and is discussed in Hymes' *Astronomy*, 1840, and by Ferguson.

In another work, *On the Measure of the Horologium*,[2] that may be genuine, a semicircular instrument is described, upon which were marked in twelve radial columns the lengths of a man's shadow corresponding to the hours of the day during the twelve months. The instrument was made of a piece of metal or wood about 5 inches in length and was provided with a radial index movable about a central point, the 'umbilicus'.

The Transmission of Arabian Learning to Oxford

In the thirteenth century the seeds of Arabian learning began to germinate in Europe among men of western race. The science of the Moors in Spain had brought them European reputation: Emperors and

[1] 'Inferiora receperit', the meaning of which is obscure.
[2] Bede. Basel, 1563 edit., p. 464.

Kings became their pupils and patrons. Natural science in the west began to put forth the first shoots of the tree that has grown so mighty.

We trace the origin of our western knowledge in matters of astronomy to some three or four sources.

The *Almagest* or Arabian version of Ptolemy's work was translated from the Arabic into Latin about 1230 at the instance of Frederick II. The astronomical manuals of some of the Arabians were abstracted and reproduced in Latin by Sacrobosco in his little text-book, *De Sphaera*, which, with the *Alfonsine Tables* published by Alfonso X, King of Castile, became part of the equipment of every astronomer for the next two or three hundred years.

Johannes de Sacrobosco (*c.* 1220) was a noted teacher of Astronomy and Mathematics in Paris, where he died in 1256.[1] His name is variously written Sacrobusto, Sacrobuschus, or John of Holywood or Holybush, or John Halifax. He was born at Halifax and is said to have studied at Oxford as a young man before going to Paris.

The study of astronomy had almost been abandoned owing to the difficulty of procuring the works of the ancient writers. Sacrobosco gave a fresh impetus to the science by abstracting the writings of Alfraganus and Albategnius, and thereout he compiled his well-known text-book *De Sphaera mundi*.[2] It has been described as a good book considering the bad times, but the author was unfortunately not a practical observer. His work, however, attained to a wide circulation and passed through 59 editions, holding the field as the text-book of astronomy for three centuries. A special translation into English was made by W. Thomas for the use of a member of Magdalen College, Prince Henry, son of James I.[3] And to come to a still more modern associa-

[1] Both Vossius, *De scientiis mathematicis* (1650), p. 179, and Kästner, *Gesch. der Math.* ii. 310, publish the inscription on his grave, but the two versions are different!

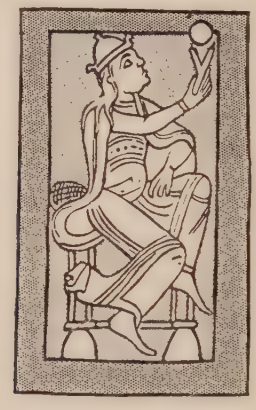
[2] Bodl. MSS. 7195, 7196. Sacrobosco mentions the *Almagest*, and has been stated to have derived some of his knowledge from it, but Dr. Dreyer assures me that this was not the case.

[3] *The Book of John de Sacro-Busco that treateth of the Sphere*, by William Thomas for his pupil Prince Henry, to whom he addressed the following letter mentioning the translation: 'My good

tion, Sacrobosco may be said to have numbered our first Astronomer Royal among his pupils. John Flamsteed, born in 1646, picked up, when at school, a copy of the *De Sphaera*, and was so fascinated by it that he determined to devote himself to astronomy.

The special works on the Quadrant both by Sacrobosco and by Robertus Anglicus of Montpellier, 1271, will be more particularly referred to in the chapter on that instrument.

It was at this period that Oxford, and more particu-



ASTRONOMER OF XII CENTURY MEASURING THE SUN'S APPARENT DIAMETER.

larly Merton College, came to the fore as a centre of astronomical study and teaching.

The earliest illustration of an English astronomical instrument in Oxford is in a twelfth-century manuscript,[1] that is inscribed *Sum liber Radulph Hopwood.*

Lorde,—I coveted to have had this booke better written than it is, and for that purpose committed it to a Scrivener in London, who, insteede of doing it himself, hath made one of his boies copy it: and hath also in divers places erred in the figures. It grieveth me to be so deceaved, and so much the more, that I shulde give you a thinge so rudely handeled. Your owne to commaunde WILLIAM THOMAS.' Sotheby's *Sale Catalogue of the Halliwell Library*, 1840; J. O. Halliwell MS. 23.

[1] MS. Bodl. S.C. 2144.

An astronomer is engaged in measuring the apparent diameter of the disk of the sun with a pair of compasses. The legs of the instrument seem to have been made of two pieces of wood of unequal lengths and to have been furnished with metal points. The shorter leg was hinged near the middle of the longer leg, the end of which served as a convenient handle.

Three other astronomers (?) are portrayed in the same MS., and on other pages are good drawings of constellations.

In the twelfth century wandering scholars, like ADELARD OF BATH, brought back the rudiments of physical and mathematical science from Cordova and other southern towns where such studies could flourish. In northern Europe the demonstrative sciences had been neglected, owing, as John of Salisbury would have us believe, to the mistranslation of parts of Aristotle's works that related to physics, for which he rebukes his teachers.

Not satisfied with the teaching of the most learned professors in Paris, where English scholars took their place as one of the 'nations' of the French university, many a student travelled to Italy and Spain impelled thither by the desire to draw nearer to the fountain-head of knowledge, and on his return found hundreds ready to reverence the 'master', and to sit at his feet until the advent of one more newly arrived.

The greatest of these travelled scholars, and one whose acquaintance with Greek and Arabic enabled him to take full advantage of the knowledge to be obtained in foreign countries, was the pupil of Edmund Rich of Abingdon, our 'Doctor mirabilis' ROGER BACON (1214–92). His marvellous discoveries and turns of thought, his use and knowledge of instrumental methods, bring him at every turn close to the science of the present day. He is generally recognized as the first great physicist in the modern sense of the word, though we have no means of knowing exactly how much he learnt from those with whom he may have studied when abroad, or how much was due to his astounding and inventive genius. He is unfortunately reticent as regards the construction of his instruments; perhaps he hardly realized that such information would be required

a thousand years after his death. For our present purpose it suffices that his improved clock, his lenses and burning glasses, and his telescope entitle him to the most honourable mention in any history of the origin of astronomical instruments; while to him we owe the earliest Astronomical Observatory in Oxford.

We learn indirectly of the existence of costly astronomical instruments in the thirteenth century from Bacon's complaint about his own lack of them. Such instruments, he wrote, 'are not to be found among the Latins, nor could they be made for two or three hundred pounds'. 'Without mathematical instruments no science can be mastered . . . Besides, better tables are indispensably necessary, tables on which the motions of the heavens are certified from the beginning to the end of the world without daily labour, but these tables are worth a king's ransom, and could not be made without a vast expense.'[1]

He had done his utmost. Between 1250 and 1267, four years after the completion of his first astronomical work the *Computus Naturae*, he had spent 'more than £2,000 on account of the cost of books, experiments, instruments, . . . and the like', but far more was required. 'Unheard, forgotten, buried' was the pathetic epitaph that the first great advocate of experimental science composed for his life work.

John Henry Green suggests that Bacon's teaching fell upon barren soil. That may have been true of the more scholastically-minded of his hearers in Oxford, but there were a few who cherished the pregnant words that fell from the master's lips or were contained in his written notes. And among his hearers there must have been some of those who contributed to the success of the young school of science in Merton College. His teaching bore fruit when, three hundred years later, Digges from a Baconian manuscript reconstructed a telescope.

[1] Bacon had perhaps heard that Alfonso had completed his planetary tables in 1272 at a cost of 40,000 ducats. Our Nautical Almanac must have cost the nation much more!

Oxford Astronomical Instruments of the Fourteenth Century

In a book of *Canones de usu instrumentorum astronomicorum* of the year 1350,[1] the author 'because', as he declares in his opening sentence, 'the most noble science of astronomy cannot be well understood without instruments', enumerates the following:

Instrument of John Campanus.

Equatorium of Master John de Lyners.
MS. Digby 168, ff. 64v–65.

Equatorium of Profacius, Temp. **Edw. II.**
MS. Ashmole 1522.

Albion of the Abbot of St. Albans.

All of which appear to have been mechanical contrivances for finding the places of the planets. (See p. 234.)

And to these must be added the **Rectangulus,** the **Navicula,** the **Semissis,** and the **Turket.**

Albion. 1326–7.

Invented and constructed by Richard of Wallingford, Abbot of St. Albans (p. 48).

An excellent copy of the descriptions of the Albion and Rectangulus are contained in a manuscript given by John of Westwyke to the monastery of St. Oswyn at Tynemouth. This manuscript afterwards passed into the hands of Thomas Horsley, and then *c.* 1633 into those of Archbishop Laud, with whose books it came to the Bodleian. It is MS. Laud Misc. 657.

The *Tractatus Albionis* (sometimes referred to as *Canones*) is divided into four parts.

Part i, beginning 'Distanciam centri differenter solaris a centro terre una cum elongatione solis ab auge circuli differentis'. ff. 2–10.

Part ii. On the Construction of the Albion, begins 'Albeon ad instar planispherii' on f. 10v, and ends on f. 20, dated at the conclusion 'completum est hoc opus cum adiutorio dei, Anno Xti 1327 inchoante'.

[1] MS. Digby 57, ff. 130–2.

We have printed this part with illustrations of the several parts of the Albion in the Appendix to this volume, p. 349.

Part iii. de Utilitatibus, mentions 32 purposes for which the Albion is serviceable. ff. 20v–31.

Part iv includes tables appropriate to the use of the instrument, and in this copy there is a local 'Tabula ascensionum signorum in circulo obliquo in latitudine 55 graduum Tynemuth'. ff. 31v–42v.

Then follow two short notes *De Saphea* and *De Astrolabio* and at the end of all is a 'clausula', which ought to have come at the beginning of the book,—'Ex collectis Symonis Tonstede S.T.P.', ff. 43–4. On f. 45 are notes on the nature of the alterations made by Symon Tonstede 'both in the book and in the instrument'.

Rectangulus. 1326.

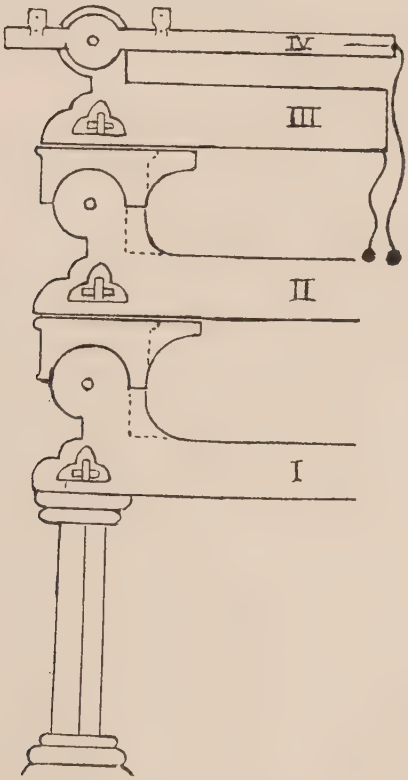
Invented and constructed by RICHARD OF WALLINGFORD.

So far as we are aware this useful instrument has never been described in print before. It consisted of four brass rules hinged to one another and mounted by a swivel joint on the top of a pillar. The lowest rule (I) was engraved with a scale. The uppermost rule (IV) was provided with pin-hole sights and a plumb-line which would have reached the divided scale on rule I. Rules II and III were hinged in the manner shown in the figure and could be inclined to make any desired angle with rule I, which must have remained in a horizontal plane.

Wallingford's Rectangulus is of especial interest to us because it is the oldest English Astronomical Instrument known, of which the inventor has left us a sufficiently detailed account, to enable us to reconstruct it after six hundred years by his method. See p. 337.

We have in Oxford three MSS. on the Rectangulus, and all three are illustrated with working drawings showing the construction of the instrument. Two of these, MS. Laud Misc. 657 and MS. Digby 168, agree with one another in most details, but C. C. C. MS. 144 differs in one important respect, namely, in the adoption of a scale divided in sixes, instead of a scale divided in fives on the lowest rule. In other words the difference between duodecimal and decimal systems had been realized.

Moreover the drawing of the complete instrument in the Corpus manuscript is the only one which shows plumb-lines hanging from the upper rules, a very important detail in the construction of the instrument. The wedge that holds the rule on the pillar-pin is shaped

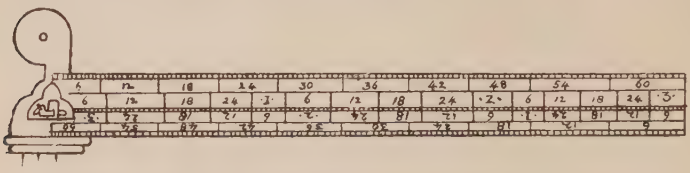


WALLINGFORD'S RECTANGULUS, 1326.
C. C. C. MS. 144, f. 80.

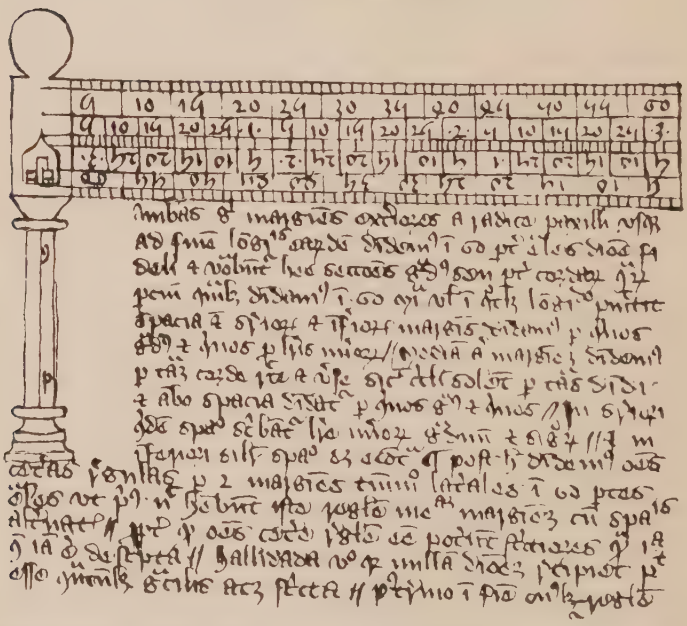
like a horse more distinctly than in the other MSS.; so that we have come to the conclusion that the Corpus MS. represents the Treatise most nearly in its original form.

The *Treatise on the Rectangulus* was written in two

parts. Part i. On the Construction. Part ii. On the Use of the Instrument. At the end are two Tables. The first, *Tabula ad inveniendum arcum per cordam*



LOWEST RULE OF RECTANGULUS, WITH SCALE IN SIXES.
C. C. C. MS. 144, f. 80.



PILLAR AND LOWEST RULE OF RECTANGULUS, WITH SCALE IN FIVES.
MS. Laud Misc. 657, f. 47.

versam, giving to the fourth sexagesimal of a degree all angles $\sin^{-1}\frac{m}{60}$ for all integral values of m from 1 to 60. The second is for nearer approximations for angles near 90°.

Turquet. **Temp. Edw. II.**

MS. Ashmole 1522, f. 177.

The Turquet or Torquetum was an instrument in which two graduated circles are fixed in two planes at right angles to one another. Nasr ed din is believed to have been the first to devise a Torquetum *c.* A.D. 1260, and Regiomontanus (1436–76) has been quoted as an original describer of the instrument. But we have in the Bodleian Library a far older MS., in which the construction of a Turquet is admirably shown by the neat diagrams that illustrate this early MS. which was written before 1350, and which is printed in the Appendix, p. 370.

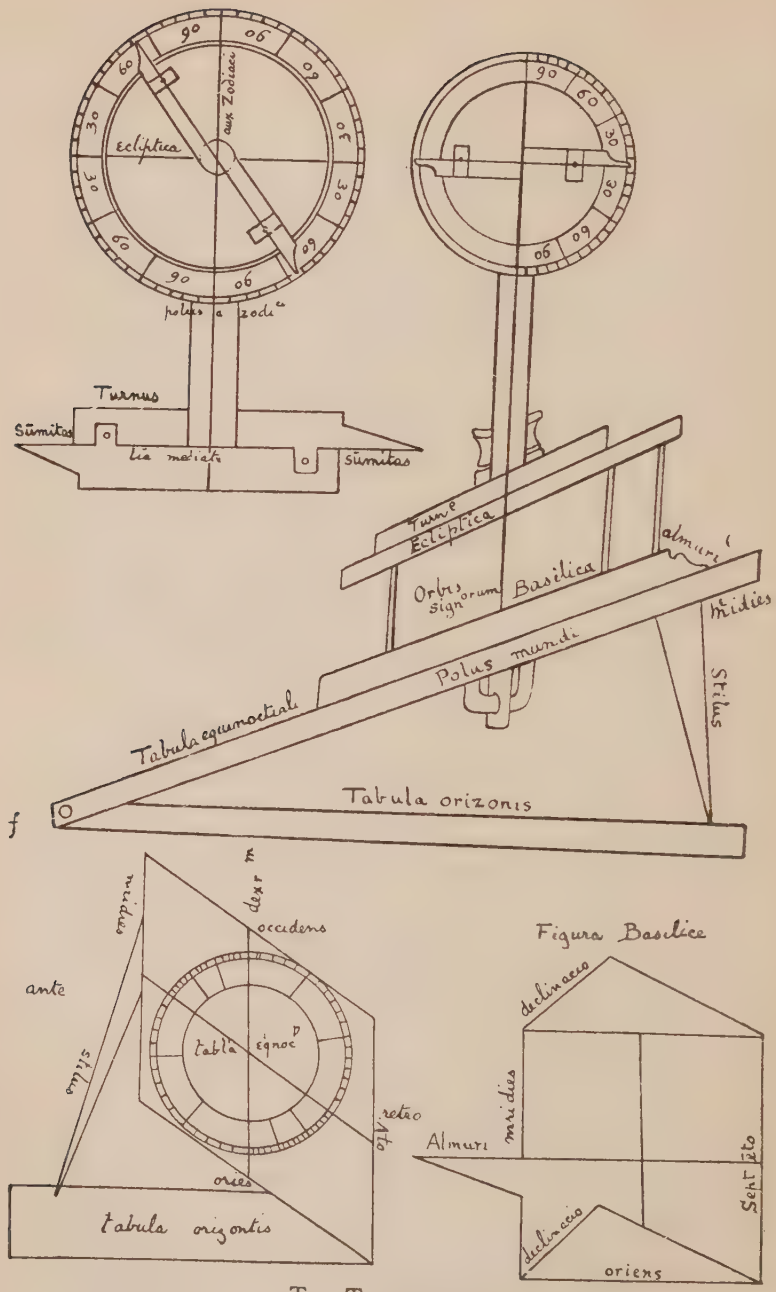
In spite of the lack of perspective in the drawings it is clear that to a base plate or *tabula orizontalis* was hinged an inclinable *tabula equinoctialis*, the inclination of which could be regulated by the length of a strut or *stylus*, the length of which would depend upon the latitude. At right angles to the tabula equinoctialis (and not inclined to it as shown in the figure) was the polar axis mounted on a rotatable *basilica*, the position of which could be read by the *almuri* over the graduated circle or *orbis signorum* on the tabula equinoctialis.

Above the basilica there appears to have been a two-ended index with pinhole sight vanes fixed to the polar axis, for making measures in right ascension, in the plane of the ecliptic; and above all was a vertical circle with alidade and rule for measures of altitude. In the diagram the altitude circle is graduated '30-60-90' in each of the four quadrants.

The altitude of an object sighted by the alidade was measured by a *Semissis* or hanging semicircle from the centre of which hung a plumb-line.

The author of the treatise is still unknown to me, but it may have been one Franco of Lüttich *c.* 1060 to whom a *Tractatus Torquati secundum Magistrum Franconem* in the Halliwell collection has been attributed.

The Turquet became a very popular instrument in the fifteenth and sixteenth centuries. In 1470 Regiomontanus quotes Geber (*c.* 1145) as an inventor. 'Machina collectitia Gebri Hispalensis, industrie admodum contexta, quippe quae omnia Ptolemaei instrumenta jocundo quodam compendio mirifice complectitur. . . . Huic spectabili machinae Torqueto nomen jam pridem fuit.'

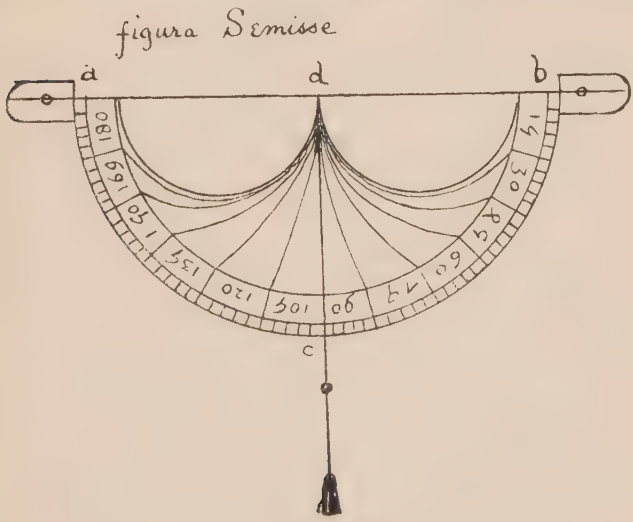


THE TORQUETUM.
WORKING DRAWINGS TO SHOW CONSTRUCTION, *c.* 1350.
MS. Ashm. 1522, f. 176v.

A more finished production was the Torquetum with Semissis of Peter Apian,[1] *c.* 1530, of which a large coloured figure is printed in his sumptuous *Astronomicon Caesareum*; and a further repetition of previously printed descriptions was printed by J. Schöner of Nuremberg, of which we have an English version in MS. Ashmole 425, which also includes the manufacture of the Staffe and of Ptolemy's 'Great Ruell'.

Semissis. **Temp. Edward II.**
MS. Ashmole 1522.

The clearly drawn figure shows that the Semissis was a semicircle used for measuring altitudes, with diametrically disposed pinhole sight vanes *a*, *b*, and a plumb-line

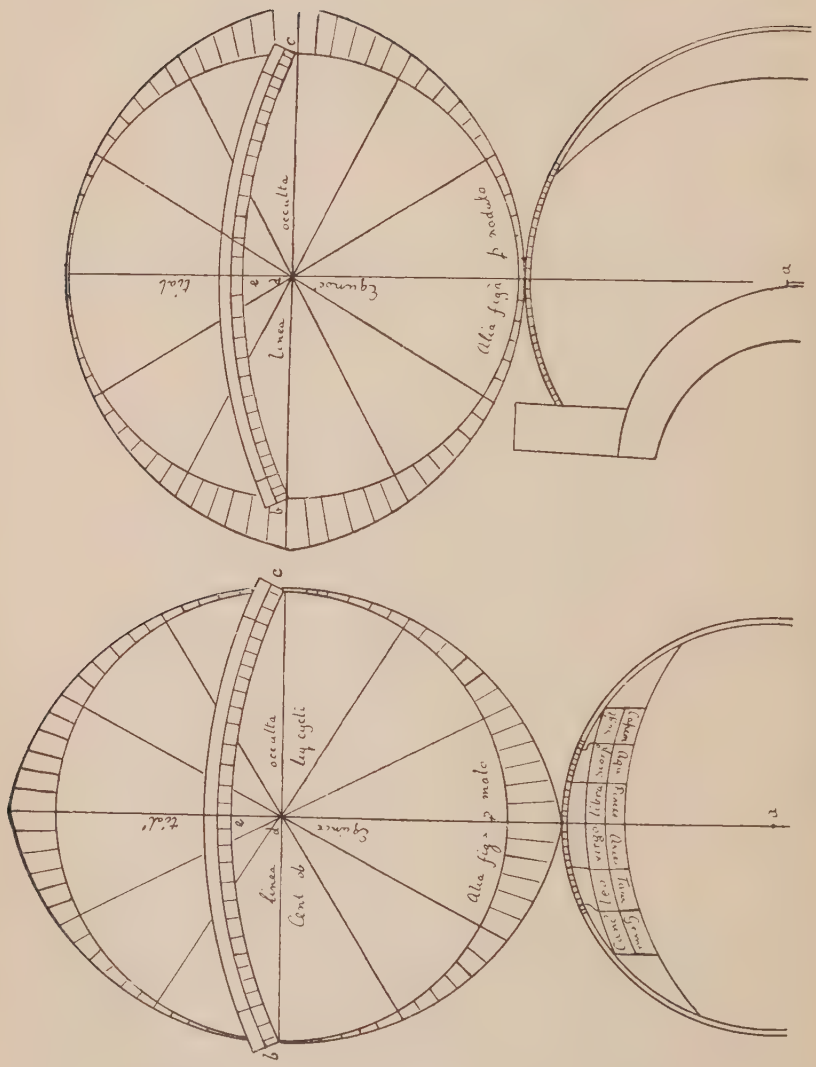


THE SEMISSIS.

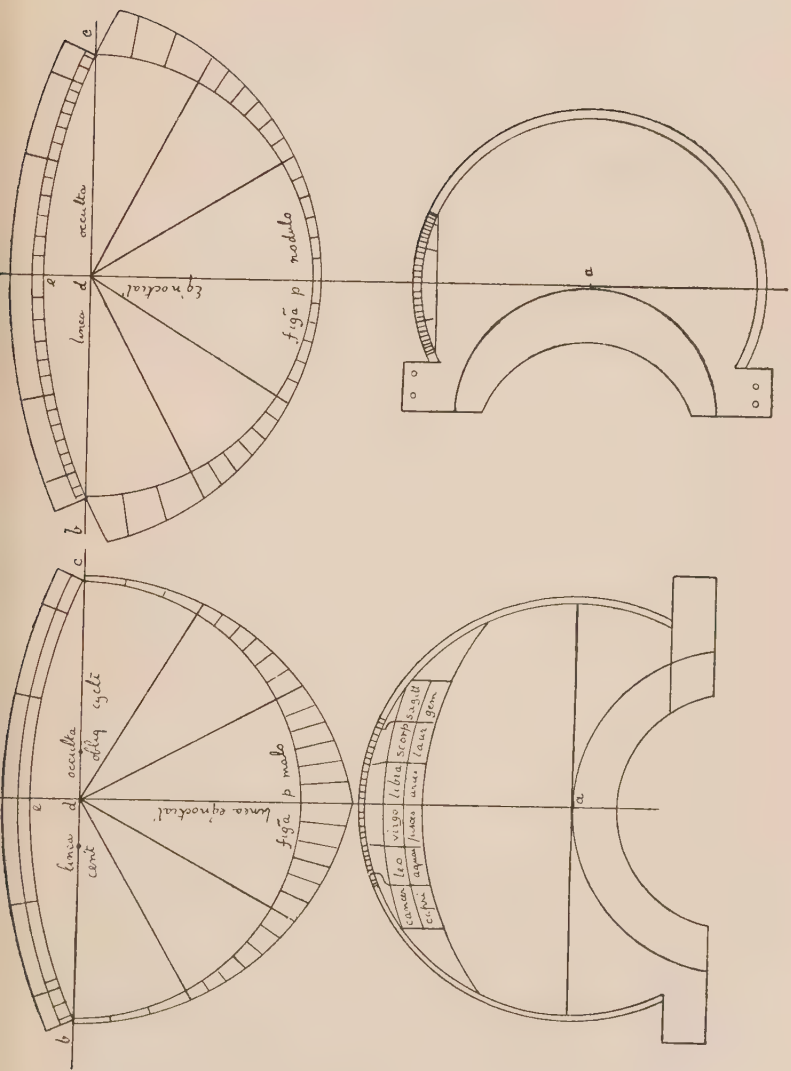
hung from the centre *d*. The rim of the semicircle was graduated into divisions, each = 3°, numbered by fives 15, 30, 45 up to 180. Within the rim are two 'instrumenta horarum', as if it were a double quadrant of an early type.

Certain tracts on the Semissis are also contained in the fourteenth-century Cambridge MS. Gg. vi. 3, f. 323.

[1] Apian, *Instrument-buch*, 1532.



NAVICULA DE VENETIIS. *MS. Bodley* 68, ff. 44-43v.



NAVICULA DE VENETIIS. *MS. Bodley* 68, ff. 45, 44v.

Navicula de Venetiis. MS. Bodley 68.

The art of making this long-forgotten instrument is described in the above-mentioned book, which apparently belonged to John Enderby of Louth, chaplain,[1] who probably flourished at the end of the fourteenth century. This volume then passed into the possession of the abbot of Coldingham, and later into that of John Chaunteler of Oxford (early sixteenth century). It also contains a description of the Annulus of John of Northampton, Chaucer's Astrolabe, a volvelle, f. 46, multiplication table, f. 47, and a sinecal quadrant, f. 48.

The description begins, 'Ad constructionem Navicule de Veneciis tria ad minus sunt instrumenta valde necessaria,' and is printed in the Appendix, p. 375. It is accompanied by working drawings (pp. 38, 39), which we reproduce here, but which must be studied with the description.

The ship-shaped plate from which the instrument takes its name was provided with two sight-vanes, each pierced with two pin-holes; and along the lower margin is a scale of the Signs of the zodiac. The 'mast' referred to in the description is not shown, but was pivoted at the point *a*: a latitude scale was marked upon it. The plumb-line used with the instrument is not shown either. The upper figures are marked with lines including the *linea equinoctialis* and *linea occulta* of astrolabe plates. The expressions *figura pro malo* and *figura pro nodulo* refer to the 'mast' and to the equator.

The instrument appears to have been a modification of the Arabian *zaouraq* (= small ship, Lat. *navicula*), of which Sédillot has given a description[2] and a figure. The zaouraq was composed of two plates. On one plate or *shafiah* were traced the three parallel circles, the twelve Signs, the fixed stars, almucantars, azimuths, hours of time, and the equal hours, &c. The other *shafiah* was ship-shaped and carried the 'languette', corresponding to the 'malus' or mast of the Navicula. It is applied to the first plate so that its curved sides fall exactly on the tropic of Capricorn and on the latitudes

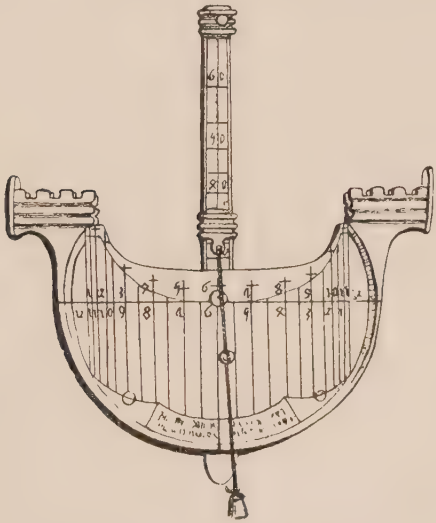
[1] In a table of latitudes of towns on f. 39, opposite the latitude of York, is the entry *Anthonius Askam doctor astrologie dicit S.S.*

[2] Sédillot, *Mémoire*, p. 182.

for which it has been constructed. The mid-line of the 'mast' marks the middle of the sky.

A rough sketch of the same instrument occurs in MS. Digby 98, ff. 75–7.

The Navicula was represented in the fifteenth century by a form of sundial, now very rare, of which one example is in the Evans collection. It is shaped like a ship with raised turrets at the ends and a swinging mast. The foot of the mast can be moved to right and left over



German Ship Dial, *c.* 1450.
Evans collection, Scale $\frac{2}{3}$.

a scale of zodiac signs, causing the mast to travel over an area similar to that of the trigon of signs in other instruments, which work on the same theory. A slider on the mast gives the adjustment for latitude. The altitude of the sun is taken by the two pin-hole sights in the turrets. The bead on the plumb-line gives the time.

The Italian form of the Ship Dial, the 'Oriuolo in forma di Nave', is described in Orontio Fineo *Opere*, 1587, pp. 70–73.

THE MERTON SCHOOL OF ASTRONOMY

BOUT twenty years before the death of Roger Bacon, we note the beginning of a change in the whole system of English University education, a change which profoundly affected the course of experimental science, and perhaps came about partly in consequence of his teaching. WALTER DE MERTON formulated statutes (*c.* 1264–74) for a College in Oxford, founded expressly to train the 'secular' clergy, i. e. 'to provide men for all the professions; for the clergy in the 13th century, besides their spiritual duties, were the civil servants, the physicians, the artists, the historians of the time'. The scholars of the College were to take no vows; they were to be free from the hindrance of ritual observances; so long as they were genuinely pursuing the student's life, they might reside and enjoy the opportunities for study that the College provided.

Success was immediate. In a little more than a century Merton College sent out six Archbishops of Canterbury; the best training to be had in England for physicians was obtained within its walls; the works of the Merton astronomers acquired a world-wide reputation. Thus the Oxford of the fourteenth century was second to no other university in scientific attainment, but the cult of natural science was largely confined to Merton College.

It may be asked how it is that histories of astronomy have so little to tell us about these astronomers of the fourteenth century. THOMAS ALLEN (1542–1632) of Gloucester Hall, the most famous mathematician in the Oxford of his day, has supplied the answer. Nearly all the works of the Merton School of Astronomy disappeared from the College Library during the Visitation in the early part of the reign of Edward VI, when books relating to all subjects were burned or sold

as waste paper. Not less than a cartload of valuable MSS. is said to have been taken from Merton Library. Fortunately Allen was able to rescue a few of the scientific codices which had belonged to Rede and others. These books were acquired later by Sir Kenelm Digby, and with his MSS. came to the Bodleian Library.

The following list of the more eminent members of Merton College in all faculties was compiled by Bale: but as my friend Mr. Salter has pointed out, not all the names are on the Bursars Rolls, and friars like R. Bacon could only live in a friary and Benedictine monks like Richard of Wallingford and Lambourne must have been at Gloucester Hall, where alone Benedictine monks might lodge.

De collegio Martonensi viri eruditi

Tempore regis Edwardi primi

Ricardus Walyngforde qui fecit instrumenta astronomie.
Thomas Abyndon.
Rogerus Bacon.
Gualtherus Burley.

Sub Edwardo 2

Joannes Gadesdene.
Ricardus Maydeston.
Ioannes Abyndon.
Magister Burneby.
Ioannes Dumbleton.
Nigellus de Waner.

Sub Edwardo 3

Ioannes Ashenden, astrologus qui summam composuit.
Ricardus Billyngham qui tabulam philosophie ac logice laboriosissime composuit.
Bredon doctor in medicinis qui multa edidit.
Rogerus Swyneshede, philosophus.
Radulphus Strodus poeta nobilis, qui carmine elegiaco librum fecit, qui vocatur fantasma Radulphi.
Magister Albon.
Thomas Wyke.
Magister Teukesbury.
Ioannes Wyclyff, doctor.

Sub Ricardo 2

Gualtherus Brit astronomus qui theoricam fecit omnium planetarum.
Ioannes Chilmarke philosophus, qui scripsit tractatum de actione elementorum.
Thomas Colby.
Magister Whelpynton.

Since no comprehensive account has as yet been published of the achievements and methods of the members of this our first great school of Astronomy in England, and as examples of their instruments and original copies of their observations are still extant, we have collected a few biographical details in the hope that the task of producing an adequate edition of these ancient astronomical works may not be long delayed.

Among the first band of scholars who advanced scientific learning and helped to train a younger generation, we number RICHARD OF WALLINGFORD, WILLIAM GRIZAUNTE, M.D.,[1] and JOHN MAUDUIT, who were probably in residence together and all contempories of SIMON ISLIP,[2] the patron of WILLIAM REDE.

OXFORD ASTRONOMICAL TABLES

Roger Bacon had declared that for advance in Astronomy new and better Tables were indispensable. At the time of his death astronomers were still dependent on the Tables of ARZACHEL.[3] Early Calendars, as for example that for 1292 in the Bodleian Library,[4] were still constructed on the basis of these tables; as was

[1] The physician W. Grizaunte or William English, Fellow of Merton 1299, has been stated to have been the father of Pope Urban V, who promoted William Rede to the Bishopric of Chichester, but another parentage has been suggested by the *D.N.B.* Bale and Pits ascribe to Grizaunte the following works: 1. *Speculum Astrologiae*, 2. *De Qualitatibus Astrorum*, 3. *De Magnitudine Solis*, 4. *De Quadratura Circuli*, but none of these is now known to exist.

[2] Simon Islip, Fellow of Merton 1307; Archbishop of Canterbury 1349–66; died 1366. So satisfied was he with the beneficial influence of 'secular' education that he himself founded a college of mixed monks and seculars on the site of Canterbury Quadrangle of Christ Church at Oxford in 1361. It was, however, monasticized four years after his death. A clause in his will bears testimony to his eminently practical nature: he left 1,000 of his best ewes to improve the breed of the sheep of the monks of Canterbury (Somner's *Canterbury*). His life (Cotton MS. Julius B III) appears to have been written by Rede.

[3] It is frequently stated that the Alfonsine tables were completed in 1252 at Toledo, but Andalo di Negro of Genoa gives 1272 as the date, and this date is expressly given in the introduction to the tables printed in T. iv of the *Libros del Saber*. They would not have been available in England at the time of Bacon's death.

[4] Kalendarium sequens extractum est a tabulis tholetanis anno domini 1292. factum ad meridiem civitatis tholeti que in Hispania

probably Walter Odington's Almanack for the year 1301 for Evesham.[1]

Harleian MS. No. 941 was 'made at Oxynforde be the new Kalendere and proved in all the university', but no truly English tables had as yet been prepared. The construction of appropriate tables was the work of the early Merton astronomers, and owing to their conscientious labours the name of Oxford in the fourteenth and fifteenth centuries came to have that place in the public estimation which Greenwich holds to-day.

The Alfonsine Tables appeared in two forms. The tables in the original form were compiled by two Jewish astronomers, Jehuda ben Mose and Isaac ibn Sid, between A. D. 1263 and 1272.[2] They differed from the better-known tables that were printed in many editions between 1483 and 1641, in that they show no trace of the sexagesimal division of time, and that the 'signs' used were zodiacal signs of 30°, and not signs of 60° as in the printed version. These characteristics have enabled Dr. Dreyer[3] to recognize thirteen tables representing the original Alfonsine Tables among our Oxford MSS. and in codices associated with the works of the members of the Merton School of Astronomy.

In one early codex[4] the tables begin with the year 1320, but in the others examined by Dr. Dreyer they are for 1340 to 1600, showing that although the Alfonsine Tables must have been known in Oxford in 1320, they did not come into general use before 1340.

That the table of the mean longitudes of each planet for every twenty years was really constructed 'super meridiem civitatis Oxon' was proved by computing a number of places of the sun and moon both from the printed tables and from the MS. tables. The latter were found to correspond to a meridian 16^m east of the meridian of Toledo, and this is exactly the supposed

scita est cujus meridianus non multum distat a meridiano medii puncti Hibernie in quo 3 continentur f. 2. Bodl. MS. fourteenth century.

[1] Walter Odington, *An Almanack for the year 1301 for Evesham.* Camb. Ii. 1, ff. 13–32.

[2] Preface to the tables in the *Libros del Saber de Astronomia del Rey Don Alfonso X.*

[3] Dreyer, *On the original form of the Alfonsine Tables*, Monthly Notices R. A. S., Jan. 1920.

[4] MS. Laud Misc. 594.

difference of longitude between Oxford and Toledo, according to the introduction to the MS. tables.[1]

In the Oxford version the succeeding tables of corresponding motions 'ad annos Christi expansos' from 1 to 20, the table of the apogee of sun and planets, showing the changes caused by precession, and the table of inequalities closely resemble the corresponding original Alfonsine Tables, but the table of latitudes has been improved. Dr. Dreyer points out that the conclusion is inevitable that in these early Oxford Tables we have the original Alfonsine Tables in the form in which they were issued from the Toledo Observatory about the year 1272. The original lengthy introduction does not appear in the Oxford Tables, its place being taken by a shorter one written by William Rede, which is quoted on p. 57.

The more recent sexagesimal version of the Alfonsine Tables is believed to have been due to John de Lineriis, who wrote a short introduction (*Quia ad inveniendum*) to them in 1322.[2] A longer canon beginning *Tempus est mensura*, and drawn up by Johannes de Saxonia, a pupil of de Lineriis, appears to have superseded the short canon:[3] it was printed in 1483.

The sexagesimal tables were adopted in Paris and, spreading to other continental countries, appear to have supplanted the original tables, but at Oxford the local tables, based on the original form of the Alfonsine Tables of 1272, flourished during the second half of the fourteenth century and remained in use in the beginning of the fifteenth century.[4]

An interesting point in the history of planetary tables which seems to demand further investigation is the exact relationship between certain Oxford Tables and the Spanish Tables of Salamanca.

Tables for the meridian of Oxford which are believed to be due to William Rede start with radices for 1348, the year in which the Black Death came to England. Similarly, in the *Tabule ad meridianum Salamantinum*[5]

[1] Dreyer, *Monthly Notices R. A. S.*, Jan. 1920.

[2] MSS. Digby 168, f. 145; Magd. Hall ii, f. 148^{v}.

[3] MSS. Digby 168, f. 135^{v}; Magd. Hall ii, f. 124^{v}.

[4] The codex MS. Ant. Wood D. 8, ff. 67–85, in the Bodleian Library contains tables beginning with the year 1400 (J. L. E. D.).

[5] MS. Canonici Misc. 27, ff. 33^{r}–147^{r}.

the 'anni collecti' are 1348, 1368, 1388, &c., to 1628. In *Tabulae resolutae* the 'anni collecti' are 1428, 1448 . . . 1808,[1] and in the version of Salamanca tables printed by Schöner in 1536 the 'anni collecti' go from 1388 to 2008.

It is possible that all these were adapted from the Oxford Tables of William Rede of which we have at least three copies.[2]

ALFONSINE TABLES IN THEIR ORIGINAL FORM, REDUCED TO THE MERIDIAN OF OXFORD, CONTAINED IN CODICES IN OXFORD (Dreyer, *l. c.*)

Codices.	Mean longitudes for meridian of Oxford.	Motion in years.	Auges.	Equations.	Canon.	Radix.	Anni expansi.	Latitude tables.
Laud Misc. 594	1320–1600	1–20	—	—	—	1348	Up to 10,000	2 sets
674	1340–1600 and single years	40, 60 . . . 10,000	—	Yes	—	1327	1–20	—
Digby 17	1340–1600	—	—	—	—	—	—	—
48	1340–1600	1–20	—	Yes	Rede	—	—	—
57	1340–1600	—	—	—	Rede	1348	—	—
97	1340–1600	—	Yes	Yes	Rede	—	—	—
A. Wood D. 8	1400–1600	—	Yes	Yes	Rede	—	—	—
Ashmole 1796	1340–1600	1–20	Yes	Yes	Rede	—	1–20	—
Magd. Hall	—	1–20, 40 . . . 2,000	—	—	—	—	—	—
C.C.C. 144	—	1–20, 40 . . . 4,000	—	Yes	—	—	—	—
IN CODICES IN LONDON								
R. Astr. Soc. Codex	1340–1600	1–20 . . . 10,000	Yes	Yes	Rede	1348	1–20	Yes
Sloane 407	1340–1600	—	Yes	Yes	—	—	—	—
Egerton 847	1340–1600	—	Yes	Yes	Rede	—	—	—
889	—	1–20 . . . 8,000	—	—	—	—	—	—
Harley 1009	1340–1600	—	—	—	Rede	—	—	—

[1] MS. Canonici Misc. 499, ff. 72r–118v.

[2] MS. Laud Misc. 594, f. 70; MS. Digby 57, f. 97v; and R. Astr. Soc. Codex, ff. 36v and 37r.

John Maudith. The first of the calculators of Oxford Tables was John Maudith or Mauduit, renowned both as physician and astronomer. He is supposed to have been elected Fellow of Merton about 1305, and to have filled the office of Bursar in 1311. He was teaching in Oxford in 1340, and may well have lived there at least till 1346.

His contribution to trigonometry has already been alluded to. His scientific reputation rests on his astronomical tables 'mirabiliter inventis in civitate Oxon. MCCCX', according to a Cambridge MS.[1] Of his works the first two of the following are in the Bodleian Library[2]:

1. *Tabule facte in Oxon Mawduth 1310.*[2]
2. *Tabula ascensionis signorum in arculo obliquo Oxon cujus latitudo est 51 grad. et 50 min verificata Oxon A.D. 1310.*[2]
3. *Parvus Tractatus editus a magistro Johanne Mauduth super quattuor tabulis mirabiliter inventis in civitate Oxon. MCCCX.*[1]

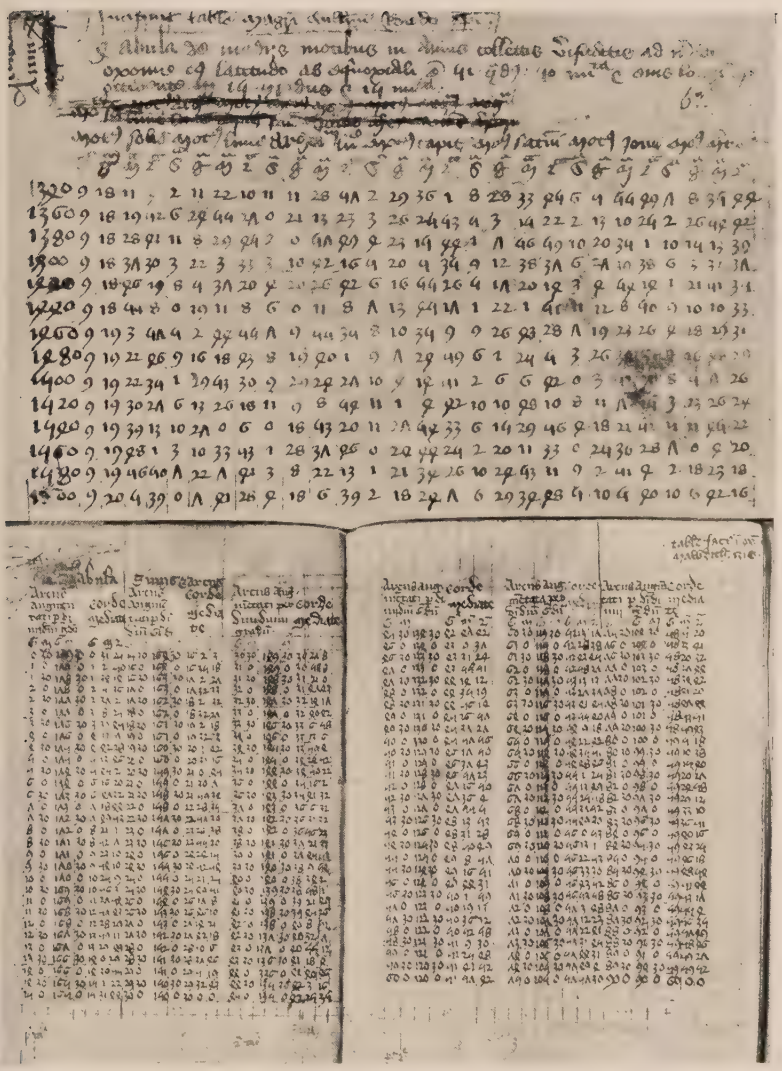
The four Tables are

i. De chorda et arcu recto et verso, et umbris.
ii. De arcu aequinoctiali elevato, et horis et arcu diei.
iii. De altitudine stellarum.
iv. De ascensionibus regionistriae.

A photograph of a neatly written copy of his *Tabulae augmenti longissimi diei supra diem equinoctii pro omni terra habitabili*, marked in the right-hand top corner 'tabule facte in Oxon, Mawduth, 1310' is reproduced on the plate facing p. 48.

Richard of Wallingford (1292?–1336) had the advantage, exceeding that of mere book-education, of inheriting manual skill from a practical father. He was the son of a skilful blacksmith at Wallingford, and his many inventions show the result of inherited genius and early training in handcraft. He spent six years at Oxford during part of which he is said to have held a fellowship at Merton (Leland). In later life he became

[1] MS. Camb. Gg. vi. 3, f. 45.
[2] MS. Laud Misc. 674, ff. 67–72.



WILLIAM REDE'S TABLES, 1340–1600

MS. Ashmole 191, f. 62

MAUDITH'S TABLES, 1310

MS. Laud Misc. 674, f. 69

Abbot of St. Albans, coming after three Abbots under whom the House approached complete bankruptcy, yet by attending to its temporalities with scientific care, he was able to place the fabric in a thoroughly good state of repair: to increase the revenues by his care of the live-stock: and he placed a check on the rascality of his bailiffs.[1]

Needless to say he did not satisfy every one.

His best known mechanical work was an astronomical clock constructed for St. Albans about 1320. The first important public clock in England is said to have been erected in 1288 at Old Palace Yard, Westminster. The St. Albans clock was so much in advance in construction that it was described as then without a rival in Europe: motions of the sun, moon, and stars with the ebb and flow of the tides were elaborately depicted on it. Edward III censured the expenditure of so much money on such an object, but Richard replied that when he himself was dead there would be no one who could complete the work. The clock, made *magno labore, majore sumptu, arte vero maxima*, was considered by Bale, who appears to have seen it, as the greatest curiosity of his time. Richard left a handbook explaining its proper use, that the clumsy or ignorant monks of St. Albans might not injure it.

In his manuscript works he has left instructions for the making of two instruments. The first of these was the 'Albion' (=all-by-one) made in 1326, identified by Leland[2] with the clock at St. Albans, but it seems rather to have been an equatorium for showing the positions of the planets. Wallingford himself described the Albion as an *instrumentum geometricum* and contrasts it with an almanac, an *arismetricum instrumentum*. The Albion was modified by Simon Tunsted. See pp. 31 and 349.

His second instrument, the Rectangulus, included an adjustable rule carrying sight vanes, which was hinged above three other rules also with hinges between them. With such an instrument altitudes could be readily measured and compared. The construction and method of use of both of his instruments are explained in works that are still extant. See pp. 32 and 337.

[1] L. Williams, *Hist. St. Albans.*

[2] *Comment. de Script. Brit.* 1709, pp. 404–5.

1. *Tractatus Albionis* 1327.
   Inc. 'Albion est geometricum instrumentum.'
   MSS. Laud Misc. 657; Corp. Chr. Coll. Oxon. 144; Camb. Univ. Libr. Mm. iii. 2; B.M. Harley 80.
2. *De arte componendi Rectangulum.* } 1326—the year Albion was made.
   Inc. 'Rectangulum in remedium.'
   MSS. Laud Misc. 657; Digby 168, f. 61; C. C. C. Oxon. 144; Cambr. Univ. Libr. Ee. iii. 61, f. 6; Harley 80, f. 54.
3. *Ars operandi cum Rectangulo.*
   MSS. Laud Misc. 657; Harley 80.
4. *Quadripartitum de sinubus demonstratis.* } MS. Digby 178.
5. *De sinubus et arcubus in circulo inveniendis.*
6. *Exafrenon prognosticorum temporis* or *De indiciis astronomicis.*
   Inc. 'Ad perfectam noticiam.'
   MSS. Digby 180, 194, and an English translation in MS. Digby 67,[1] ff. 6–12[b], entitled 'An introduction to the art of astrological calculations'. Beg. 'Tho the perfecte knawledge of the domes of the crafte of astronomye.' The translator says in Chap. 1: –'The tables are of myne awne makyng. For the tables of the Abbot of Sancte Albones [are] made full of erroures, and þat I trewe bee throwgh the vices of writers and nott of the worshipfull clerke and prelate þat þe treites made.' The Tables are for the years 1385–1388 which is probably the date of the translation.
7. *De opimetris.*
8. *De eclipsibus solis et lunae.*
   MS. C. C. C. Oxon. 144.

Simon Tunsted or Donostadius was a Minorite friar born at Norwich who in 1351 became the regent master of the Minorites in Oxford. He has already been mentioned as an improver of the Albion,[2] and as a modifier of the *Canones* of Richard of Wallingford. He died and

[1] Digby 67 was once 'Liber domus scolarium de Merton in Oxon ex legato M. Joh. Reynham sacre pagine professoris et quondam socii ejusdem domus' (fourteenth century).

[2] For an account of his additions to Richard of Wallingford's instrument, see MS. Laud Misc. 657, printed on p. 369.

ho the pfecte knawlege of the domes of the crafte of astronomye. ye which be the zowlynge
bynde. And howeth forthe of the effectes of
planetes. ||| First it is nedful for to knaw ye
entynge of the domes in to the first aymite
astis. for yare begynnes principaly ye
lumynyng of the entynge of alle ye
le zore. || And also yat fro ye entynge
the domes in to yaneew be gynnes ye cha
gyng of the moneth of aprile. || And so
other signes of the zodiack. And other
neythe of the zore. || And yat is ye tok
ng. for comonly in the myddis of the
neythe ye tymes bew made gynne als to
effectes of the domes. ||| Also it is spedfile
to knaw ye entyng of the domes in to
gees of the zodiack fore particular de
e yat folowes ye ayone in conjuction & op
tion & of planetis. || And ye knawle
of this is ordanid forto knaw ye gree
endente opon ye orizont in ye same ty
|| fore after the gree distendente thy
de mesure thyn howse. ¶ The scende
moste knawe ye crafte to seche what
of the zodiac rise upon thyn orizont
he moment of the howre, in ye which
wold gyfe thyn. Some fore gyfe ar
ewn of the meynyng of the fremamet
planetis tabis gifis effectis & ryn
sporye || And yfore the philosophre
nde & crafte to departe all ye frema
t in. 12. partes. The which partes be
d howse. || And yan began at the
ndent. fore it is principal. fore after ye
losophre in ye bookes of ye heven &
e warldis be the vertu of ye planetis
howse moste in the est. And so be the
ndent yu salt mesure all yt
. 12 howses. || ¶ The thirde y most
re ye strengthis & vertues substancial
l the planetis. Of the wich fame kane
w aunes bynde, wher fore ar oberyd
colde, dryg & moyste. As it shall show
we chapitres. || And of strenghe is y
kane of the bynde of the signe yat yay

bew in. || And yan ar callid. 4. dig
nytes. ye which bew. Domg, exaltatio
triplicitas, termini, & facies. & ca
what is the end of yees bew. y salt see
in yare chapitres. || And wes cond y to.
And this ye substance of domes. fore
knew ye dignytes kanghes moste fo
ye & strenghes of thew. || Abowte the
which philosofis trabolis besily. ||
¶ The forthe is. y moste knawe ye fre
neythis yat be fallynge to yaid be cow
tayne mobynes in yare differences,
or elt in yare spiraclis. As is station.
progression, & retrogradation, and of
yare distance fro ye domes. As is risy
nges & goyng downe, & comyng towards
or nygh the cenyth, & goyng awaye
warde. Alle yat it is in gynne parties
of chapre differences. || And alle yese y
salt knawe. whew y hafe made ex
tione of the planetis be ye degrees
& ye centis, & of thyngs als it shewis
be yare cayons of yaid. And be tab
les yat ar callid. Almanac. ¶ The. 4.
fifth chapitre is. y moste knawe forto
ordre in figures of kewsynge ye plane
tis in yare signis. || And to knawe wh
ich is ye sextile aspecte in conjuction. ||
And alse which is ye vertis & ye effecte
of ich ond of yame. || And witt y wolde
yat al planete is comforted by al good
aspecte of and of planete. || And this y
tis is feblis be and evil aspecte. &
also y moste knawin to drawe ou
the lorde of the zore, of the thynges of
ye monethes, & of the howre. ¶ The
sexte & ye liste is. y moste knawe dome
& tolle be fore thynges yat ar to come
kyndely be ayisament & gedeynge
to gedir of all yees yat I kane sayde. ||
Alle yese so yat y sayde now thynge be
fore certanely, but y wyll tele yat
y kane lefe no ynge behynde yat I
kane spekyn of. As saye ye philosofis
in alenchis. ¶ The yat lokes and to fore
thynges. ar lightly beciled. || wel e-

ICHARD OF WALLINGFORD'S EXAFRENON. ENGLISH TRANSLATION, *c.* 1385.
MS. Digby 67, f. 6.

was buried in the nunnery of Bruisyard in Suffolk in 1369.

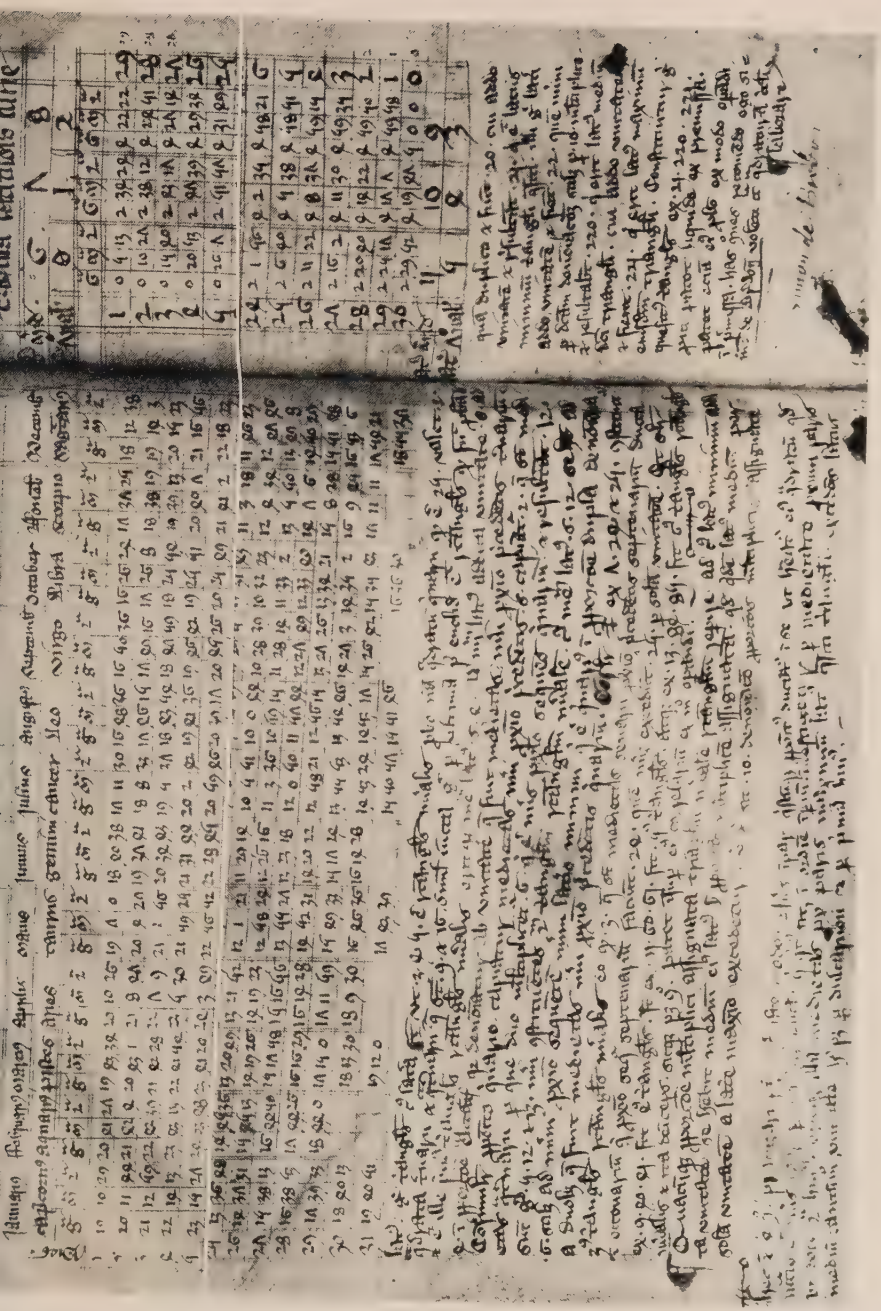
Simon Bredon or Biridanus, a native of Winchecombe, was originally a Fellow of Balliol who migrated to Merton, and 'by the severe discipline there used' became a noted physician, mathematician, and astronomer. He took the degree of M.D. in 1330. He wrote an *Arsmetrica*[1] and was a student of the Almagest, on the first three books of which he has left a commentary.[2] He wrote on the subject of the eclipse of 1345 and a *Theorica planetarum* is generally attributed to him.[3] At his death, by a will dated 1368, he bequeathed his extensive scientific library to several Colleges, and his larger and smaller astrolabes to Merton College and to his brother-fellow William Rede respectively (*Notes and Queries*, 5th Ser. vii. 405). Some mathematical notes in his own handwriting are preserved in MS. Digby 178, ff. 11v–14, a volume that has belonged to T. Allen and to J. Dee in turn. On ff. 11v–13 are Bredon's *Conclusiones quinque de numero quadrato*, in his own hand, with a note 'Has conclusiones recommendo *ego Simon de Bredon* volenti circa quadraturas circuli laborare'. On ff. 13v– and 14 are short mathematical and astronomical notes and a reference to the *Perspectiva* of Vitellio, and Apollonius of Perga. A further specimen of his handwriting is contained in MS. Digby 179, in Merton MS. 250, and in MS. Digby 176, ff. 71, 72, which has been ascribed to Rede in the Catalogue. I am grateful to Mr. P. S. Allen for pointing out these resemblances. Ff. 12v and 13, which we reproduce, show Bredon's notes at the end of his own copy of an Oxford Almanack for 1341.

The catalogue of the library of any man of science of the fourteenth century is a matter of such unique interest that we make no apology for reprinting Bredon's catalogue in full.

[1] MS. Digby 98, f. 109.

[2] MS. Digby 168, ff. 21–40 (fourteenth century), is believed to be written in his own hand.

[3] MS. Digby 98, f. 132, is illustrated with figures showing the Circulus eccentricus, circulus egressus, &c.



XFORD ALMANACK FOR 1344, WITH NOTES SIGNED BY SIMON BREDON

MS. Digby 178, ff. 12v, 13

List of Books and Instruments disposed of by Will by Simon Bredon, 1368

Whittlesey's Reg. 1220

Avicenna written by Ragg *Boicii de Arsmetica* *Tullii Rethorica*	To Balliol College.
— *liber magnus ystoriarum.*	To University College.
Avicenna meus melior *Rasis libri* *Galieni libri* in two volumes *geomancia* *ars medicine* *Collectorii liber* *Mesue liber* with '*thesaurus pauperum*' *Almansoris liber* with *dictis universalibus et particularibus* *Pantegrini Constantini* (*Africani*) *liber* *Ruth super antidotarium* *Aliae lecturae super antidotarium* *Heben Mesue platearum practicam* *Arnaldi de Villa nova libri* *Questiones et lecturae medicine,* 2 books *Galieni passionarium* *The[o]derici et Lanfranci et Henrici de Mandavilla liber chirurgie* *Tholomei de indiciis astronomie quadripartitum* *Haly Abenragel de indiciis astronomie* *Gebir de Astronomia* The book which I call '*Minuta introductoria astronomie*'	To Merton College.
Book of Decretals with an account of them *Book of Decrees* with Martin's 'tabula' of them	To William of Heightbury.[1]
A little book entitled '*oculus sacerdotis*'.	To Vicar of Sevenoaks.
Liber Sentenciarum (Peter Lombard).	To the King's Hall (Oriel).
Collectorii liber cum asseribus (? clasps) *et de viridibus cordis* (by Avicenna). *Bartholomei de naturis rerum.*	To Queen's College.

[1] William of Hettysbury was a Fellow of Merton in 1330 and Chancellor of the University in 1371.

Metheorum textum
Tholomei Almagesti textum } To Exeter College.
Ordinale plenarium de usu Sarum
Legenda de Sanctis
Liber de Gallico entitled *Manuel de Pecche* } To Merton College.
Astrolabium majus
Astrolabium minus. To William Rede.
Liber mineralium cum adjunctis.
Avicenne et brinni cirurgia.
Liber de collectionibus harum.
Taddei super afforismos.
Libellum de Statutis Anglie.
My quaterni *de gramatica et dialectica.*
Ysidor ethimologiarum.
Platearii Practica which begins 'amicum induit'.
Platearium with universal and particular 'dictis', with 'asseribus de corio' (= hide or leather).
Gilbertini practica.
My quaternus in which are contained:
Prefacii Almanak.
Opus de sinibus.
Albumasar minus introductorium.
Mauduit table.
Book beginning 'que in gloriosissimis'.
Albertus de lapidibus et animalibus.
Experimenta de corrio serpentis.
Betemi centilogium Arzachel canones.
Albumazer in majori introductorio.
Martini Cronica.
Girardus super viaticum cum Constantinus (*Africanus*) or *Girardus de modo medendi.*
Rosa (*Anglica*) tenuioris voluminis.
Avicenna tabula which is called 'fructuarium'.
Averois tabula.
Rasar tabula in Almansor.
Mesue tabula.
Tabula dietarum.
S[er]apionis aggregatoris tabula.
Platearii tabula.
Liber which is called '*macer' florid* (a Herbal).
Tabula super antidotarium.
Two treatises *de urinis.*
Vademecum de localibus.

In a fifteenth-century copy of the *Theorica planetarum* (MS. Digby 15) that work is attributed to Walter Bryte,

but in another copy of the book (MS. Digby 48), illustrated with figures, are the following verses:

Qui cupis astrorum septem bene scire sophiam
Hunc lege tractatum qui continet astronomiam
Namque domus Merton hanc fecerat arte potitus
Astronomus Bredon consocius atque peritus
O Deus astripotens anime Bredon miserere
Cum sanctis statuas qui dicunt Kyria chere.

MS. Digby 48.

John Ashenden, Ashindon, or Eastwood, Fellow of Merton 1338, is considered by Wood as the greatest of these mathematicians and astronomers and the founder of the school at Merton. His works are cited with respect by Pico della Mirandola. He worked in collaboration with Rede and is said to have foretold the Black Death from the consideration of an eclipse of the moon (MS. Digby 176, f. 9). But beyond the titles of his books, some of which are included in the valuable Rede Codex (MS. Digby 167) described below, we have very few personal details about him. His association with Rede is acknowledged in the first of their joint works, the *Pronosticaciones* of certain eclipses of the moon and of the *conversionum* of the three superior planets in 1345 before the first plague.[1]

The *Indiciae Eschendenenses* were completed *c.* 1348 (No. 13) ? MS. Cantab. Ii. 1. 27.

Next comes his *Pronosticacio* of the conjunction of Saturn and Mars for 23 March 1349, of the total eclipse of the moon for June 1st, and of the conjunction of Jupiter and Mars on the 7th of August 1349. (MS. Digby 176, f. 30.)

And lastly there is his joint work with Rede on the conjunction of Saturn and Jupiter in October 1365—a treatise which was finished by 'Mag. J. Eschindene' on 10 March 1357, probably about the time when he wrote on the signification of the conjunction of Saturn and Mars in Cancer on June 8th 1357.

[1] The following Eschenden MSS. are in the Bodleian: MSS. Ashm. 209, 393, 396, 576, 1471.

A copy of his *Summa judicialis de accidentibus mundi* in folio, fourteenth-century vellum, is in the Library of the Royal College of Physicians.

William Rede, Reed, or Reade (*c.* 1325-85) was Ashenden's partner in many of his astronomical computations. Owing to the fortunate preservation of the author's own copy of several of his works which were specially left to Merton and Exeter Colleges but are now in the Bodleian (MS. Digby 176), as well as of instruments that probably belonged to him, it should be possible to reconstruct the astronomical learning of his time.

Rede appears to have been studying at Oxford before 1337 (cf. MS. Digby 176, f. 71) perhaps at Exeter College, from which he was elected a Fellow of Merton in 1344, becoming Bursar there in 1352–3. His tutor was one Nicholas de Sandwych who presented him with a collection of Quaestiones (MS. Digby 216). He will always be remembered in Oxford as the builder of the Merton Library, the most attractive Library in the University, which he not only helped to endow with books, since scattered or lost, but to which he bequeathed £100 for maintenance. Rede's astronomical instruments were to be seen there in 1615 (Godwin) and there is no reason to doubt that they are there still, although absolute identification is not easy.

There is still extant a letter to Rede from one of his pupils, Reginald Lamborn (B.D. Merton, *c.* 1350–60), on Conjunctions to take place in 1368–74. In 1369 Rede accepted the Archdeaconry of Rochester and the Bishopric of Chichester. His will shows that the needs of the then young Colleges at Oxford were very present to his mind. He, to whom had been left books and instruments by others, left his library between Merton, New College, Oriel, Exeter, Balliol, and Queen's Colleges, and many of his books are still where he placed them.[1] For a detailed list, see the Appendix, p. 380.

Rede determined the position of Oxford, placing it on latitude 51° 50′ and longitude 15° and some minutes. Cyprian Leovitius, another very early astronomer and author of *Ephemerides*, determined the latitude to be

[1] In the *D. N. B.* Rede's biographer, C. L. Kingsford, states that only one of the books is where Rede placed it, viz. MS. Balliol 94. This is fortunately very far from the truth. Of the books which he presented to Merton, three are now MSS. Digby 176, 216, and 19. MS. Jesus 46, containing the Tabulae, was also formerly in his possession.

52° 44′:[1] the actual position is latitude 51° 46′ N., longitude 1° 16′ W.

LIST OF REDE'S WORKS

1337. 1. *Tabulae astronomicae.* Almanak sive Tabulae Solis pro 4 annis 1341–1344 (ad meridiem Oxon).

MSS. Digby 57, f. 32; 97, ff. 5–41 (an excellent and clear copy of the Tables); 176, f. 71; 178, ff. 11–13 (with Simon Bredon's signature). Mr. P. S. Allen considers that these two last MSS. are both in the same handwriting, i.e. that of Bredon.

MSS. Ashmole 191, ff. 62–76; 393 iv. 1; Magdalen College 182; Jesus College 46.

And in the MSS. containing the *Canones.*

2. *Canones Tabularum ad Meridiem Oxon.*

Inc. 'Volentibus pronosticare futuros effectus Planetarum'.[2]

It has been suggested that the Canones were not by Rede, but by Nicholas of Lynn.

MSS. Digby 57, ff. 40–3; 48, ff. 177–81; 92, f. 11; 97, ff. 64–71; Hertford Coll. 2, f. 51; Bodl. MS. 2589; Cambr. Univ. Libr. Ii, 27; R. Astr. Soc. Codex; Brit. Mus. Egerton 847, ff. 122–142; Harley 1009, ff. 3–11[r].

3. *Pronosticationes Eclipseos Lunae 1345* W. Rede calculavit, Joh. Ashenden pronosticavit.

MS. Digby 176, ff. 9–13.

[1] Wood, *City of Oxford*, p. 54.

[2] Rede's introduction to the use of the tables is divided into seven paragraphs (*conclusiones*) explaining the tables of mean motion and of auges, equations, oppositions of sun and moon, and the possibility of eclipses. It begins:

Incipit canon ad tabulas sequentes radicatas ad meridiem Oxon.

In nomine domini Jhesu Christi. Volentibus prognosticare futuros effectus planetarum in inferioribus istis primum secundum opus tabularum mediorum motuum oportet calculare diversitates. Sed inter tabulas nunc inuentas precisiores sunt tabule quas composuit Alfonsus Rex illustris Castelle super meridiem Tholeti. Sed istarum tabularum operatio est ita prolixa et tediosa quod vix aliqui proueniunt ad completam cognitionem planetarum. Ideo quasdam tabulas compendiosas super annos incarnationis Christi et super radices et motus tabularum Alfonsi fundatas ad leuitatem operis ordinaui et ad meridiem ciuitatis Oxonie reduxi, que distat ab occidente per 15 gradus et ab equinoctiali per 51 gr. et 50 m., cuius meridies precedit meridiem tholeti per 4 g. equinoctialis circuli, quibus correspondent 16 m. vnius hore. Vnde ad doctrinam completam singulorum motuum planetarum doctrina capitulorum sequentium diligenter est notanda.

4. *Calculation at Oxford in March 1357 of the significance of the Conjunction of Saturn and Jupiter in October 1365.*

MS. Digby 176, f. 34.

Introitus Solis in Arietem Anno Gracie 1440 . . . juxta Tabulas Magistri Rede.

A specimen of one of Rede's Tables, *Tabula de mediis motibus in annis collectis et resolutis ad meridiem Oxonie, latitudo ab equinoxiali 51 grad. 50 minuta,* for 1340–1600, is reproduced, facing p. 48.

The titles of three of Rede's short historical tracts are also given in the *Dictionary of National Biography.*

MS. Ashmole 191, f. 56.

Of the volumes that Rede presented for the use of scholars of Merton and Exeter Colleges, one, now MS. Digby 176, contains in a small space so many of the original observations and calculations of himself and other members of the Merton School that we do not hesitate to publish an abstract of its contents.

3. Will de Merle Weather records 1337–1344, ff. 4–8.
4. Pronosticaciones cujusdam eclipseos (lunae) visibilis, et conversionum trium superiorum anno Christi 1345 contingencium et primam pestilenciam precedencium, quas m. W. Reed calculavit et m. Jo. Aschendene pronosticavit, ff. 9–13.
7. Tabula ascensionum solis, lunae, et quatuor planetarum in unoquoque mense pro annis 1328–1357, f. 19.
8. Tabula ad habendum dominos annorum in 55 annis, quorum primus est annus Christi 1332, finalis annus Christi 1386, f. 22b.
10. Pronosticacio { conjunctionis Saturni et Martis 23 die Marcii; eclipsis lune universalis primo die Junii; conjunccionis Jovis et Martis, 7 die Augusti } 1349

    per Johannem Aschedene sive Esshyngdene, f. 30.
11. Significacio conjunccionis magne Saturni et Jovis que erit anno Christi 1365 in mense Octobris, completis de eodem mense 29 diebus 14 horis et 22 minutis, quam M. W. Rede calculavit et J. Assh(enden), f. 34.

    Completus est iste tractatus 10 March 1357 per Mag. J. Eschindene.

12. Epistola a Reginaldo Lambourne, monacho Eyneshamensi (ad Gul. Reed ut videtur), anno 1367 de conjunctionibus Saturni, Jovis et Martis, cum prognosticatione malorum inde in annis 1368–1374 probabiliter occurrentium, f. 40.
    'Reverendissime domine . . .'
13. Tractatus Johannis de Eschyndene de significacione conjunccionis Saturni et Martis in Cancro que est isto anno Christi 1357, in 8° die Junii, et de significacione conjunccionis magne Saturni et Jovis que erit anno Christi 1365, in 30° die Octobris, f. 42.
14. Epistola a Reginaldo Lambourne monacho simplici Eynshamensi ad quendam Johannem London, de significatione eclipsium lunae hoc anno instante 1363 sub mensibus Marcii et Septembris, f. 50.
25. Almanak solis pro quatuor annis 1341–4 super meridiem Oxonie per W. Reed anno Christi 1337 calculata et scripta, f. 71.
30. Figurae . . ., f. 90–1.

On the back of the first leaf is a note on how this volume came to be collected by Rede. It runs

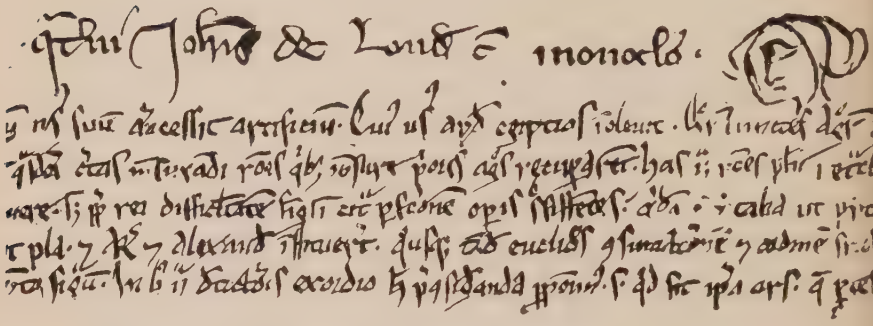
Liber m. Willelmi Reed, episcopi Cicestrensis cujus partem habuit ex dono rev. domini sui m. Nicholai de Sandwyco, partem emit de executoribus rev. patris domini Thome de Bradwardina archiepiscopi Cantuariensis, partem emit de executoribus m. Ricardi Camsale, partem ipse m. Willelmus scripsit et partem scribi fecit. Oretis igitur pro singulis supradictis, et pro benefactoribus eorundem, et fidelium animabus a purgatorio lib[era]ndis.

Reginald Lambourne. As a specimen of what must be one of the very oldest letters now in existence dealing with an astronomical topic, we print the last lines of Lambourne's letter (about the eclipse of 1363) to John of London. Lambourne, reputed of Merton, was a monk of Eynsham; we do not know which of the several Johns of London it was.[1] The book of one of them, now MS. Digby 174, is inscribed Liber Johannis

[1] The most famous John of London was a poor lad of 15, when Roger Bacon instructed him in mathematics and optics, and in 1267 sent him to Rome to present the *Opus majus* to Pope Clement IV. Some have thought him an alias of John Peckham, Archbishop of Canterbury. Another John of London was John Bever, the chronicler and monk of Westminster, who died in 1311.

de Lond. de Librario St. August. Cant'. On folio 99 is a caricature of the owner, drawn by a fourteenth-century artist on the top edge of a note-book headed,

Quaterni Joh. de Lond cum monoculo.



PORTRAIT OF JOHN OF LONDON.
MS. Digby 174, f. 99.

It is obvious from the figure that he had but one eye. Lambourne addressed him as 'Magister mi reverende, et dilecte multum in Christo et sub Christo domine, quia me disciplina jam tarde coram reverencia vestra constitutum', and ended his letter 'scripta sunt hec primo et concepta per vestrum Reginaldum monachum simplicem Eyneshamie. 27 die mensis Februarii anno supradicto [1363]. Domino Johanni London.' MS. Digby 176, ff. 50-53^{v}.

The two last of the English astronomers of the fourteenth century were John Somer and Nicholas of Lynn. They were both calculators of calendars constructed for the meridian of Oxford; and though not members of that College, had profited by the labours of the astronomers of Merton. The works of both had the distinction of being referred to with approval in a treatise on the Astrolabe by Geoffrey Chaucer.

JOHN SOMER, SEMUR, or SOMERARIUS (fl. 1383) was a Minorite astronomer belonging to the Franciscan house at Bridgewater, and was probably at Oxford in

1380. At the instance of Thomas Kingsbury, provincial minister of the order, he wrote a calendar with astronomical tables—*Tertium Opusculum Kalendarii*—for Joan, Princess of Wales, mother of Richard II; it is dated

REGINALD LAMBOURNE'S LETTER TO JOHN OF LONDON, 1363.
MS. Digby 176.

1380 and runs from 1387, the year of the birth of Richard II, until 1507.

Of this there are many copies—the illuminated MS. Bibl. Reg. 2 B. viii was perhaps the presentation copy. In it the cycles run from 1387 to 1462, but in the

Cotton MS. Vesp. E. vii, which contains also some planispheres, the cycle is 1505 to 1481. Another copy among the Queen of Sweden's MSS. at the Vatican is dated 1384. Among the MSS. of Petavius in the Vatican the Calendar is dated 1372. In Oxford we have MS. Digby 5, f. 73 (sec. xiv). Somer also wrote a *Castigation of former Calendars collected from many sources*[1] which began 'Corruptio calendarii horribilis est'.

Somer's Calendars were used by Chaucer, who, in his Treatise on the Astrolabe, declares his intention of making 'the thirde partye (that) shall contayne divers tables (of longitudes and latitudes, and declinations of the sun) after the Kalenders of the reverent clerkes, frere John Somer and frere N(icholas) Lenne.' This third part, however, is wanting.

An extracte of freer John Somerys Kalender of ille days in the yere. MS. Digby 88, f. 62b (sec. xv).

Tertium opusculum Kalendarii (A.D. 1387–1462).

MSS. Brit. Mus. Royal 2 B. viii (sec. xiv); Cotton Faustina A. II, ff. 1–12.

Cotton Vesp. E. vii, ff. 4–22; Bodl. MS. Digby 5, f. 73 (sec. xiv).

Nicholas de Linea or Nicholas of Lynn (fl. 1386) was for a time lecturer in theology to the Carmelite Order in Oxford. The work for which he is best known is his Calendar arranged for the latitude and longitude of Oxford for the four nineteen-year cycles following the year 1386, i.e. for the period 1386 to 1462.

These tables were composed at the request of John of Gaunt, Duke of Lancaster, as a continuation of the tables composed by Walter de Elvenden for the three cycles, or 57 years, which ended in 1386 (see MS. Digby 176). The calendar was in general use at the time of Chaucer and was mentioned by him.

Kalendarium, ad latitudinem et longitudinem civitatis Oxoniae compositum, 'pro quatuor cyclis decennovenalibus immediate sequentibus' annum 1386. (MS. Ashm. 5.)

Nicholas has been identified by Hakluyt, or perhaps rather confused, with an early Arctic explorer of 1360.

[1] Bale, *Script. Brit.* VII. viii.

In that year a Franciscan of Oxford, a good astronomer, 'a priest who had an astrolabe', and presumably one of the Merton School, made a voyage to lands near the North Pole, and described all the wonders of those islands in a book which he gave to the King of England (Edward III)—and inscribed in Latin 'Inventio Fortunatae'. But the unnamed Franciscan astronomer is more likely to have been some person other than our frere Nicholas—Hugo of Ireland has been suggested, and the confusion may have arisen from his having sailed from the port of Lynn. One member of Merton, John de Vilers, is quoted by Brodrick as having travelled in northern latitudes *c.* 1336, 'Vilers itineravit ad Boream',[1] but Mr. P. S. Allen has drawn attention to the fact that 'in partes boreales' is a frequent expression for visiting Northumberland.

The tables of Nicholas had only been issued for some five years when GEOFFREY CHAUCER sent his little son Lewis up to Oxford and put him under the tutorship of N. Strode. Although the reputation of Oxford as an astronomical school stood high, there was apparently no astronomer of outstanding merit at Merton at the moment, although JOHN CHYLMARK, the author of the *De accidentibus Planetarum*, had been recently lecturing in *Scholis Oxoniae in plateâ Scholarum positis*; or else the poet had little confidence in the ability of Oxford dons to teach the practical use of instruments. Whatever the reason for this lack of confidence, we owe to it the first and the standard text-book on the Astrolabe in the English language.

Chaucer introduces to us the typical Oxford science-man of his time in the person of one 'hendy' Nicholas, a poor scholar, or tutor, who lived apparently as an unattached student in the town. He

> Had learned art, but all his fantasy
> Was turned for to learn astrology.

He also appears to have turned his study to his personal advantage by forecasting the weather for farmers and foretelling the future for their wives. He

[1] Brodrick, *Mem. Merton*, p. 199.

had a laboratory at his lodgings, which is described in the following lines:

> A chamber had he in that hostelry
> Alone withouten any company,
> Full fetisly y-dight with herbs swoot,
> And he himself was sweet as is the root
> Of liquorice or any setewale.
> His Almagest, and books great and small,
> His astrolobe belonging to his art,
> His augrim stones layed fair apart,
> On shelves couched at his beddes head.

A good idea of the instrumental equipment of Merton College during the fourteenth and fifteenth centuries is conveyed by the following list collected by my friend Mr. P. S. Allen from documents in the College Library, which show how much was lent and has been lost.

List of Astronomical and Mathematical Instruments mentioned in Merton Library Documents

Catalogue ⟨*c.* 1320⟩:—
(A[1])

44 Astrolabium inclusum in quodam casu de grosso corio xiiis. iiiid.
51 Astrolabium inclusum in quadam casula de corio grosso xs.

Eleccio ⟨*c.* 1410⟩:—
(D)

7 Astrolabium magnum cum quinque tabulis
62 Astrolabium antiquum cum vna tabula
16 Spera solida cum capsula
75 Spera coēm eneaēm
25 Quadrans Campani
37 Equatorium ligneum cum epiciclo
50 Equatorium eneum cum epiciclo

Eleccio 1418:—
(E)

152 Quadrans eneus (D. 25)

Eleccio 1451:—
(F)

4 Astrolabium me[9] cum 5 laminis (D. 7)
93 Astrolabium magnum et me[9] cum tractatu eiusdem
180 Astrolabium antiquum cum duplici rethe

202 Astrolabium cum vna ⟨tabula⟩ (D. 62)
136 Equatorium eneum cum epiciclo in dorso cum voluellis solis et lune (D. 50)
27 Triangulum Rede cum capsula in quo inscribitur n. [? nomen] Rede.
69 Triangulum cum cursore mobili.
48 Spera solida cum capsula (D. 16)
114 Carta marina cum capsula et circino de laton
225 Carta marina
158 Saphea cum allidada lignea

Before the close of the fourteenth century the paramount importance of the study of astronomy in Oxford was so fully recognized that WILLIAM OF WYKEHAM, in the very first section of his Statutes for New College, ordained that two of the number of the Fellows should devote themselves specially to the science of astronomy.

THE FIFTEENTH CENTURY

During the first years of the fifteenth century the fame and the methods of the Merton School spread as far as Cambridge, where the new learning found disciples who constructed other astronomical tables for their own meridian. Evidence on this point is contained in one of those early codices of scientific books and observations which belonged to and was partly compiled by John Holbrook, Master of St. Peter's College, Cambridge, 1418–31. The volume contains a copy of the Tables of William Rede and of the *Canones*, also Holbrook's Commentary thereon. Then follow the *Tabulae Cantabrigienses*, made at Cambridge in 1430. These tables have been described as the first advance in science made by Cambridge. In a brief but very curious preface, Holbrook mentions the *Tabulae Oxonienses* of William Rede, and points out errors in them, lest his attempt should be considered 'supervacaneum aut inutile post tabulas Oxonienses quas egregius vir Willelmus Cicestreñ antistes composuit'.

This highly interesting *Codex Holbrookianus* contained much of the same matter as the earlier Oxford codices. It contains several Astronomical tables of value.

Suchwelles *Scheme of Nativity of Henry VI.* (Astrologer Royal.)

Walter Britte *Theoria planetarum* inc. Circulus ecentricus et egresse.

Bredon *Tabula declinationis solis.*

Canones super tabulas cordarum et umbrarum.

Johannes de Lineriis *Tabulae.*

Holbrook's notes thereon, dated 1428.

Johannes Walter *Tabula equacionis domorum*
Fellow of Worcester College.

C. Kyngeston Observations on the eclipse of the sun on 24 May 1517, 9 h. 57 m. made at Cambridge.

Radices motus octave spere ad eram Incarnationis per meridies Tholeti, Oxonie, Londonie, Colchestre, Parisius, et Cantabrigie.
The computation for Cambridge is added in Holbrook's handwriting.

Tabulae Alfonsi regis Castelle.

Canones super Alfonsi tabulas.
In Holbrook's autograph.

Canones Tabularum Willelmi Reed.

Wm. Reed *Tabulae.*

Holbrook Commentarius in tabulas precedentes.

Tabulae Cantabrigienses by J. Holbrook.
The only copy known; MSS. in the Bodleian (MSS. Ashm. 340 and 346) contain the Preface only.

Novae Tabulae Cantabrigienses.
In Holbrook's autograph.

Meanwhile the succession of Astronomer-physicians continued at Merton, but the lamp of astronomical learning began to burn less brightly than it had done in the fourteenth century, while the light of medicine began to glow with a growing flame.

At Merton there are records of John Killingworth, who was succeeded by a group of the 'noted astronomers', Walter Hart, elected Fellow 1437-8, and afterwards among the first twenty Fellows of All Souls; John Curteis, M.D., elected 1442; Henry Sutton, M.D., elected 1458; John Stacy, elected 1462, who was associated in his studies with Blake, a chaplain of Merton; Thomas Kent, who predicted the hard winter and famine of 1490.

Not a very distinguished band of men, yet there were none more so in England. They apparently made no original contribution to knowledge, for the stimulus

afforded by original research was wanting; they lived on their educational capital, the accumulated learning of their predecessors. At the most they devoted their science to professional requirements.

For the astronomical history of the fifteenth century one must go to Samarkand where Ulugh Beg, the grandson of Tamerlane, was observing and cataloguing the stars in 1433; and to Germany, where George Purbach (1460) was publishing trigonometrical tables, where John Müller of Königsberg, better known as Regiomontanus (1436–76), was forming tables and contriving the first printed Almanack (1472)[1]; to Tübingen, where Johannes Stöffler was teaching the use of the Astrolabe and was printing Ephemerides and Almanacks that had the greatest reputation of any in Europe for half a century.

The Sixteenth Century

By the sixteenth century Germany had become a very wealthy country, and the prosperity of individuals led to the advancement of scientific learning. Both the Hanseatic League with its monopoly of the northern trade, and the southern States with their close commercial relations with Venice, brought new wealth to individuals and afforded leisure for the pursuits of science, art, and learning. Material prosperity is an essential condition for the progress of knowledge. The great names of the century are Copernicus (1473–1543), Rheticus (1514–76), Tycho Brahe (1546–1601), and Kepler (1571–1630).

In Oxford in the sixteenth century, however, we do not meet with the name of any practical astronomer in connexion with Merton College[2]—Philip Dense,[3] elected

[1] After an interval of 25 years Müller's Almanack was followed by the first almanack printed in England—the *Sheapeheard's Kalender*, a translation from the French, printed by R. Pynson.

[2] Members of the College occasionally borrowed astronomical books and instruments from the Library, as is shown by entries in the books (*Merton Register*, ff. 246, 252: ed. Salter, *O.H.S.*, pp. 490, 499).

Eleccio 1519:

Spera cum laminis	Spera parva
Astrolabium antiquum	Magna spera
Spera solida	Plat' cum laminis nova
Quadrans cum capsula	Spera fracta

Subwarden records, 13 Sept. 1520.

Recepi a magistro Moscroff 14 instrumente astronomie.

[3] Dense's Tables were kept in the Library 'till times of reforma-

1500, died 'morbo pestilenti' in 1507, is only remembered as a composer of tables—until SIR HENRY SAVILE came to Merton in 1561, and about 1619 founded the chairs of Geometry and Astronomy which still bear his name. And it may have been due to his influence that in the previous year, 1618, some observations of a Comet had been made at Oxford.[1]

Interest in astrology never flagged, all the known facts and methods of science were pressed into its service, and several of the more able practitioners of the art acquired considerable wealth. JOHN ROBINS (1500?–1558), elected a Fellow of All Souls in 1520, and afterwards chaplain to Henry VIII, canon of Christ Church and Windsor, 'became the ablest person of his time' in mathematics and astrology, not excepting his friend Recorde, whose learning was more general. The following MSS. by him are still in existence:

De Stellis Fixis. MS. Digby 143.

De Portentosis Cometis (to Henry VIII). Trin. Libr. Camb. MS. O. I. II.

De Accidentibus futuris (to Henry VIII). MS. Ashm. 186.

Tractatus de Prognosticatione per Eclipsin.

Observationes Astrologiae. Brit. Mus. MS. Sloane 1743.

Annotationes Astrologiae. Brit. Mus. MS. Sloane 1773.

There are extracts from the two last in Bodl. MS. 3467, Seld. Arch. B. 79, p. 149. (*D. N. B.*)

To Trinity College belonged the learned astrologer THOMAS ALLEN, who, by reason of some aversion to taking orders, migrated to Gloucester Hall about 1572, and died there in 1632 at the age of 96, after sixty years' residence. Dudley, Earl of Leicester, made use of him for casting nativities, and Queen Elizabeth consulted him about the New Star that appeared in Cassiopeia.

tion, when they were taken out and made waste paper'. Wood, *Athenae.* Mr. P. S. Allen informs me that there is a record in Merton to the effect that on one occasion Dense was 'gated' in College for a month for taking part in a brawl, in which three townsmen were killed by a certain member of the College. Dense, taking a bow and arrows, went out with him, 'et sagittavit'! His 'bag' is not recorded.

[1] *Observationes ad Phenomena Cometae.* A. D. 1618 factae Oxon. per Standish. Quarto paper MS. Halliwell 100. A Transcript from MSS. in Sion College.

'In those darke times astrologer, mathematician and conjurer were accounted the same things, and the vulgar did verily believe him to be a conjurer. He had a great many mathematical instruments and glasses in his chamber, which did also confirm the ignorant in their opinion, and his servitor, to impose on Freshmen and simple people, would tell them that sometimes he should meet the spirits coming up the stairs like bees.'[1]

To him, more than to any other person, we owe the preservation of the works of the early Merton astronomers.

List of Instruments considered important by Regiomontanus, 1472, mentioned in his *de Torqueto*, printed with other *Scripta* by J. Schoner in 1544.

Portable instruments.

Opus Albionis.

Sphera solida.

Aequatorium . . . ex quo errantium stellarum motus, luminarium configurationes et defectus colliguntur. A chart with the circumference divided into 360° upon which the positions of planets can be entered.

Saphea = a variety of Astrolabe.

Astrolabium vulgare = Planispheric Astrolabe.

Quadrans horarius = Sundial.

Cylindrus = the Pillar dial.

Regula of Hipparchus.

" of Archimedes.

Fixed instruments.

Ptolemy's Astrolabium annulare.

" Regula magna (or parallactica).

Armilla solstitialis } described in the *Almagest.*
Large Quadrant }

All are of Greek origin except the *Saphea* and the *Albion.*

We have now arrived at a period in which no great work was being done in Astronomy in England. The instruments that were in common use do not appear to

[1] Aubrey, *Lives.*

have been of the size necessary to secure great refinement of measurement. The older types of instrument had not yet become obsolete, and the modern types had not yet appeared. The following is an interesting list of Astronomical Instruments in use in the time of ROBERT RECORDE, *c.* 1530–50, of All Souls College (see vol. i, pp. 99 and 189):

Astrolabe	Tunsteede's rules
Plaine Sphere	Albion
Saphey	Torquete
Quadrante of divers sorts	Astronomers staffe
Chylynder	Astronomers ringe
Ptolome his rules	Astronomers shippe
Hipparchus rules	'A greate many more.'

'Ptolome his rules' had a more distinguished career on the continent than in England, where it was used more by surveyors than by astronomers. There as the **Triquetrum** it was preferred to the Quadrant, because of the greater ease with which accurate graduation can be applied to a straight line than to an arc; and it remained in use until the end of the sixteenth century.

The Triquetrum consisted of two hinged arms of equal length while a carefully graduated third rule gave the means of measuring the angle between the two former by the aid of a table of chords.

Copernicus had an 8-foot triquetrum made of pine-wood and divided by ink marks, the two equal arms into 1,000 parts and the long rule into 1,414 parts. This instrument was inherited by Tycho, who set it up at Uraniborg in 1584. He did not, however, value it as much as he valued his measuring instruments with graduated arcs.

The Radius metricus or geometricus or astronomicus is mentioned in 1600 by Peter Ryff, *Quaest. Geom.*, pp. 116–35, with diagrams to show its construction and use.

A similar though less extensive list of instruments is mentioned by Recorde's contemporary Dr. W. Cuningham of Norwich, author of the beautifully printed *Cosmographicall Glasse*, to which he is believed to have contributed wood-blocks of his own engraving. We reproduce his figure of Ptolemy's Rules or Triquetrum.

Far larger and more costly instruments were needed before any further advance could be made. For the next chapter in the history of the science we must turn

to Denmark, where during the last quarter of the sixteenth century the application to astronomical science of quadrants, sextants, and other measuring instruments without the aid of telescopes was brought to fullest perfection by that prince of observers, Tycho Brahe (1546-1601), who 'accumulated more new facts about the heavens than had been revealed since the date of

It is made of 3. peaces, beyng 4. square: As in the Picture where A. F. is the first peace or rule.
A.D. The seconde.
G.D. the third rule.
E. The Foote of the staffe.
C.F. The Plumrule.
C.B. The ioyntes, in which the second & third Rulers are moued.
K.L. The sighte holes.
I. The Sonne.
H. The Zenit, or verticall pointe.
M. N. The Noonestead Lyne.

PTOLEMY'S RULES 1559.
After Cuningham.

Hipparchus'. To him is due the first realization of Seneca's forecast, as to the possibility of predicting the path of a comet; he recorded and analysed the position of the planet Mars, and estimated, with a degree of accuracy hardly surpassed at the present day, the irregularities of the lunar motion—i. e. the equation of the centre, and the evection known to Ptolemy, the variation undiscovered by Abul Wefa, the change of Inclination, and the inequality of the Nodes. Tycho's one error was his condemnation of Copernicus, who in his view

'moved the Earth from its foundations, stopped the revolution of the firmament, made the sun stand still, and subverted the whole ancient order of the universe'.

The wealth of observations recorded by Tycho was inherited by his disciple and assistant John Kepler (1571–1630), who after nine years of meditation and calculation gave to the world the great Laws which reconciled the observations of his late master with the System of Copernicus.

1. *The planets move round the sun, but in ellipses, not in circles; and the sun is in one of the foci of the ellipse.*

2. *The motion is not uniform; but the planet moves over equal areas, bounded by lines drawn to it from the sun, in equal times.*[1]

Nine years later Kepler enunciated his third law in a work dedicated to James I.

3. *The squares of the periods of the revolution of the planets are to each other as the cubes of their mean distances from the sun.*[2]

No greater testimony can be borne to the sterling excellence of the instruments of Tycho Brahe than that they led to the discovery of these three Laws, and that they formed the basis of the *Rudolphine Tables*, which were afterwards, in 1627, given to the world under Kepler's editorship. So great was the confidence of Kepler in the eternal truth and greatness of his discoveries that he wrote, 'the book is written to be read either now or by posterity—I care not which: it may well wait a century for a reader, as God has waited 6000 years for an observer'. It was the knell of the old astronomy.

But the establishment of a physical interdependence between the heavenly bodies has not been the most important factor in the further development of Astronomy. The application of a new instrument—at the time the most ingenious that human industry and sagacity could have hoped to put together—made advances easy; more than any other, it marked the beginning of a new era, of new phases of thought.

Within the short but eventful period 1609–11, the telescope had revealed to GALILEO the most surprising

[1] Kepler, *De Stellâ Martis*, 1609.
[2] Kepler, *Harmonice Mundi*, 1618.

and unforeseen truths. It showed that the face of the moon is full of cavities and asperities resembling valleys and mountains. The sun, which had been generally regarded as a ball of pure fire, was clearly seen to be sullied by a number of dark spots. A great number of new stars were discovered in every part of the heavens; the planet Jupiter was found to be attended by four moons, which moved round him in the same manner that our moon moves round the Earth; the phases of Venus appeared like those of the moon, verifying the view of Copernicus; in short, the telescope furnished new proof of the truth of the Copernican System. But, alas, that these incontestable truths should have been to their discoverer a cause of imprisonment and abjuration.

ASTRONOMICAL OBSERVATORIES

So to Friar Bacon's study: I up and saw it, and gave the man 1s. Oxford mighty fine place. Pepys *Diary*, June 1668.

TRADITION has it that the earliest astronomical observatory in Oxford was situated on the only spot that is definitely connected with the name of ROGER BACON, and the writer finds some gratification in penning these lines in a room which, more nearly than any other in the town, corresponds in situation and outlook with the

FRIAR BACON'S STUDY ON FOLLY BRIDGE.
Ingram, Memorials of Oxford.

Study. Sad to say, the original building was sacrificed[1] in the eighteenth century to an ill-considered scheme for road-widening, Oxford losing thereby a picturesque antiquity and scientific philosophers a place of pilgrim-

[1] *Dialogue concerning alterations in Oxford*; composed by Richard Hely Hutchinson and David Henry Urquhart, Gentlemen Commoners of Magdalen College, and recited at the Encoenia in 1773.

Dic age, num veteris restant vestigia portae
Nulla tibi? quid sacra ergo penetralia censes
Quo spectanda modo, qua nunc sublimis ad austrum
Stat summo de ponte *Domus veneranda* BACONI,
Relligione loci seros intacta per annos?
Hoc tibi Palladium, nunquam de sede movendum
Sacratâ, nisi quod via sat vicina molesta est,
Heu Genti nimium, velut Appia, dura Togatae.

age; for many, as did Olaus Borrichius in 1660, would have paid it the tribute of a visit.[1]

Friar Bacon's study stood on Folly Bridge, on an eyot midstream in the Thames. Old drawings show us the house placed athwart the bridge and built over an archway that spanned it: it had evidently been erected for a gatehouse. 'I cannot otherwise imagine, but that it was first built in King Stephen's raigne or in the beginning of the troblesome wars of the Barons, being then built as a pharoes or watch-tower for the defence of the city.'[2]

According to traditions delivered to Wood from eminent persons, Bacon 'did sometimes use in the night season to ascend this place invironed with waters and there to take the altitude and distance of stars and make use of it for his owne convenience in that respect, it being very necessary, situated for its vicinity to his convent by conveying him self through a backway over Trillmill into Grandpont'.

Down below, the Thames flowed through several channels; and three eyots or hams that lay between the waterways were probably then, as later in Wood's day, overgrown with osiers. Now (1917) pontoons for the Great War are being built there. The view from Bacon's window would have been much the same as that from the writer's house, before Oxford extended into Berkshire. Where the view is blocked by the new Grandpont Quarter, Bacon would have looked over a wide strath of water-meadows, crossed by a raised causeway enabling travellers from the south to reach the city dryshod, except when the Oxford flood-lake reached right out to the forest-clad slopes of Bagley Hill.

[1] Extat hodieque Oxonii *domus Rogerii Baconis*, incolis *The Howse of Frayer Bacon* appellata, quam cum ab alterâ Tamesis urbem lambentis ripâ, ostenderet mihi *Edmundus Dickinsonus*, Medicus insignis, adjecit, *Rogerium* monachorum quorundam obtrectationibus quotidie proscissum in ulteriori ripâ fixisse sibi aedes, tum nè in citeriori adeoque in urbe vivens, jurisdictioni eorundem foret obnoxius, tum ut ostenderet se tamen oculos adversariorum non defugere, sed vitae reliquo de ignorantiâ invisae cohortis triumphare. Borrichius *de Ortu et Progressu Chemiae*, p. 138, 4to, Haffniae, 1668.

Edmund Dickinson, B.A., of Merton, 1647, was practising as a physician in Westminster in 1692.

[2] Wood, *City of Oxford*.

Changes have taken place. The river's course has deviated to the south, but there is still an eyot in the middle of the bridge; the high road has been widened, raised, paved, and asphalted; all the foreground has been covered with the yellow brick walls and slate roofs of small houses; but above the panorama of chimney-pots, may still be seen the upper round of Bacon's view, the crests of Boar's Hill, Bagley and the Hinksey Hills, save only that the greenery on the skyline is now interrupted by villa residences.

It would be difficult to find any situation in the City more favourably situated for the quadrant and astrolabe observations of the first astronomers of Merton College than the raised terrace along the old town wall with an uninterrupted view to the south across the flat water-meadows. But of any regular observatory there is no record before the seventeenth century.

Before proceeding with our account we may briefly recall the stages by which the need of observatories became recognized elsewhere.

It has frequently been stated that the first instrument to be set up in the meridian by a European was set up by Copernicus about 1540. The first astronomical observatory in Europe was founded in 1472 at Nuremberg.[1] In 1561 William, Landgrave of Hesse, equipped another at Cassel with the best instruments then obtainable. The next, the more celebrated Observatory at Uraniborg, was sumptuously furnished almost regardless of expense by Frederick II, King of Denmark, for Tycho Brahe. The first stone was laid on August 8, 1576. The instruments were lost within twenty years of Tycho's death. There are, however, good illustrations of many of them all in Tycho Brahe's *Astronomiae instauratae Mechanica*, Wandesburgi, 1598, of which there is a sumptuous coloured copy in the Bodleian Library[2] bound with a MS. copy of Tycho's catalogue of a thousand stars, with the following inscription:

Henricus Wottonius
Doctis Advenis
S.

Sciat lector hunc librum complecti partim Mechanica typis

[1] See art. 'Observatory' in *Ency. Brit.* [2] Arch. Bodl. D. 32.

excusa, coloribusque depicta, quibus Ticho Brahe nobilis Danus usus est ex sua propria inventione, sumptuque Regio in rimandis Coeli Arcanis, partim prosphonetica duo Epigrammata cum inerrantium Stellarum Octavi orbis accurato Canone propria ejusdem Manu exarata (quem Cimbricum Ptolemaeum merito vocemus) et ab ipso Scriptore Marino Grimanno Venetorum tum Principi oblata haud dubie hoc consilio ut Besseriana Venetiis Bibliotheca conderentur, quae quum postea inter alios MS. codices casu coemptos in possessionem meam devenissent ex Musaeolo nostro Etonae Oxonium Almam olim Altricem meam transferri curavimus Ejusdenq praecelebri Bibliothecae perpetuo consecrari volumus: Κειμηλιον ob Authoris Memoriam ingentis Pretii

Ob Donatoris, Nullius
Anno unici *Mediatoris* inter deum et homines
CIↃ D CXXXIII Ipsis Augusti Mensis
EIDIBVS.

A hundred years after the foundation of Uraniborg the foundation stone of our own Royal Observatory was laid on the highest part of Greenwich Park by the Rev. John Flamsteed,[1] who had been appointed Astronomer Royal to Charles II.

Flamsteed's salary was £100 a year, with full permission to provide himself with the instruments he might require, at his own expense. In 1670 Sir Jonas Moore, Surveyor of the Ordnance, made him a present of a Townley micrometer, and 'promised to furnish him with object glasses for telescopes at moderate rates'.

In 1674 Flamsteed became better acquainted with Newton: the occasion which led to this acquaintanceship being the amusing one that his assistance was asked by Newton, who had found himself unable to adjust a microscope, having forgotten its object-glass—'not the only instance of the great Mathematician's absent-mindedness'. In 1676 he entered into residence at Greenwich with the very modest equipment of two clocks, a sextant, and the Townley micrometer given by Sir Jonas Moore. Seven years later he erected a Mural Quadrant by Abraham Sharp of 50 in. radius, and this was followed in 1689 by a new Mural Arc of 140° and 7 ft. radius by the same maker. In 1710 Uffenbach reported on the Greenwich Quadrant,

[1] John Flamsteed, 1646–1719.

of which he published an engraving, and stated that the observatory had very few instruments.

In the course of centuries Astronomers appeared at Oxford from time to time: among those of note were JOHN BLYSSE, M.D. (*c.* 1510), and THOMAS LYDIAT, a Fellow of New College (1525–44), famous for his calculations for a new Calendar. In September 1607 Mr. Standish saw Halley's comet at Oxford at 10½ p.m., but there was no regular observatory when Sir Henry Savile founded his Professorships of Astronomy and Geometry, but in 1613 the University made definite provision for the more convenient teaching of astronomy by devoting a room on the east side of the Schools quadrangle to the purpose, and by allotting the top room in the tower as an observatory. Here doubtless JOHN BAINBRIDGE (1582–1643), the first Savilian Professor of Astronomy, may have used the instruments of which a list is stated to be among his MSS. in Trinity College, Dublin. So far as we know, his lectures were mainly theoretical. He advertised his course by *affiches* or written papers put upon the school gate. One of these ended in the words *lecturus de polis et axis*, under which was written by an unknown hand—

Doctor Bainbridge
Came from Cambridge
  To read *de polis et axis.*
Let him go back again
Like a dunce as he came,
  And learn a new syntaxis.[1]

The second Professor, JOHN GREAVES, had a large collection of instruments, a list of which, printed in the *Catalogus Librorum Manuscriptorum* of 1697, is reproduced on the next page.

The instruments were probably kept in the triple-locked *Cista Mathematica* now standing empty in the Picture Gallery at the Bodleian Library, and they would have been used in the **Observatory on the tower of the Schools.**

At the time of her second Savilian Professor, Oxford was therefore far richer than Greenwich in her instrumental equipment.

[1] W. Pope, *Life of Seth Ward.*

INSTRUMENTA ASTRONOMICA
Muſei Saviliani
EX DONO PLERAQUE
Johannis & Thomæ Græviorum
FRATRUM SCIENTIA AC PROBITATE
PERSIMILIUM ET SEMPER MEMORANDORUM

1. *Strolabium æreum cum Reti & Planiſphærio.*
2. *Quadrans æreus radio pedum trium cum triente adminiculis adiutus.*
3. *Sextans radio ſex pedum cum limbo æreo.*
4. *Octans ferreus radio pedum duum cum pedis quadrante limbo æreo diſtinctus.*
5. *Sextans ligneus radio pedum duodecim.*
6. *Octans ligneus radio pedum decem.*
7. *Quadrantis muralis limbus æreus radio ſex pedum.*
8. *Quadrans æreus binis tubis Teleſcopicis & adminiculo inſtructus.*
9. *Quindecim pedum Teleſcopium cum vitris tribus.*
10. *Teleſcopium ſex pedum cum vitris quatuor.*
11. *Teleſcopium pedum duorum.*
12. *Horologium menſtruum cum pendulo filo æreo, minuta ſecunda commonſtrans.*
13. *Globus ligneus in cotyla lignea motitans quadranti adſerendus.*
14. *Conus in parabolam, hyperbolam & ellipſin diſſectus.*
15. *Circini magni ære armati.*
16. *Elementorum Euclidis Schemata ligno efformata.*

Any one who has climbed the spiral stair up the tower of the Schools under the guidance of our present genial Keeper of the University Archives will realize that a man must have been no ordinary mortal who on a winter night in the darkness of the seventeenth century would have left his bed to gaze at the stars in so chilly and remote a watch-tower. In the first enthusiasm of youth, perhaps; but later—?

SETH WARD, Savilian Professor of Astronomy 1649–61,[1] and afterwards Bishop of Sarum, was considered by his contemporaries to have been the first to propose a Theory of the orbits of Comets that accords with recent observations. Kepler thought that they were produced *de Novo*, quickly perishing again; Gassendi, while holding them to be *corpora aeterna*, believed them to move in straight lines. Ward, in a professorial lecture delivered in Oxford, and afterwards published in 1653, showed that it was more probable that comets were 'carryed round in circles or ellipses (either including or excluding the globe of the Earth) so great, that the comets are never visible to us, but when they come to the perigees of those circles or ellipses, and ever after invisible till they have absolved their periods in those vast orbs, which by reason of their standing in an oblique, or perpendicular posture to the eye, he demonstrated might well seem to carry them in straight lines; all circles or ellipses so posited, projecting themselves naturally into such lines.'[2]

Further work on Comets was done by R. HOLLAND, a teacher of Mathematics in Oxford, who showed how to get the angle of Parallax of a Comet, or other Phenomenon, at two observations to be taken at any one station, or place of the Earth, and thereby the distance from the Earth.[3] His method was printed at Oxford.[4]

[1] WARD resided in Wadham College in the chamber over the gate during his tenure of the Savilian Professorship. The members of the Philosophical Society of Oxford (see vol. i, p. 49) must have frequently met in his rooms. [2] Plot, *Oxfordshire*.

[3] Plot, *Oxfordshire*, p. 227.

[4] Holland, *Notes how to get the Angle of Parallax of a Comet*, Oxford, 1668. His other work, entitled *Globe Notes*, appeared in 1678 and 1684. He lies buried in St. Peter-in-the-East, in Oxford.

The prestige of Seth Ward and Warden Wilkins attracted a young Cambridge graduate, Laurence Rooke, to Wadham College, where he made observations on the comet of December 1652.[1] He died in his apartment at Gresham College on the very night when he expected to finish his accurate observations on the satellites of Jupiter, to the great grief of his brother Fellows of the Royal Society.

Astronomical studies began once more to progress in Oxford, and even the Bodleian accounts contain an entry

To Mr. Walker for ye Telescope £1 10*s.* 6*d.*

But there are no references to work done at an observatory.

Especially noteworthy on account of their remarkable variety were the suggestive proposals and achievements of that 'incomparable' genius, SIR CHRISTOPHER WREN. He is said to have anticipated Huygens in explaining the telescopic appearance of Saturn,[2] and to have formulated a theory of the Moon's Libration. Even while still a gentleman commoner at Wadham College, he turned his attention to the problem of finding the longitude at sea.[3] When elected Gresham Professor in 1657 at the early age of twenty, the application of the telescope to astronomical discovery was comparatively new, and so he spoke with natural enthusiasm of its revelations—of the physical nature of the sun, his spots and faculae, of planets and the moon, 'who to discover our longitudes by eclipsing the sun hath painted out the countries upon our globe with her conical shadow as with a pencil'. He referred to the great services which astronomy might render theology, and very rightly added that 'we need not fear to diminish a miracle by explaining it'. He held out the expectation that some one would live to receive an explanation of Kepler's elliptical theory of the planetary orbits, and this was said nearly

[1] Seth Ward, *Praelectio de Cometis*, Oxford, 1655.

[2] Wren's observations of Saturn date from January 1655, when he attempted a wax model of the planet. See his letter of Oct. 1, 1661, in Birch, *History of Royal Society*, i, p. 47.

[3] *Parentalia*, p. 246.

thirty years before the publication of the *Principia*; but Newton himself[1] allowed that the three Oxford men, Wren, Hooke and Halley, had already arrived at the Law of Inverse Squares. However, the demonstration of the Law was reserved for Newton.

The astronomical quadrant of Wren's invention was specially chosen to be exhibited to Charles II at the time of his Majesty's reception in 1663.

Plot states that of the many ingenious and useful inventions that Wren made in connexion with astronomical instruments, most, if not all, were found out while he was Professor of Astronomy in Oxford. Among the contrivances that he added to the telescope were, 'many sorts of retes, screws, and apertures, to take in more or less light, by opening and shutting like the pupil of the eye' (= Iris Diaphragm).

His improvements in grinding good glasses have been mentioned in the section on optics. Also two telescopes to open with a joint after the manner of a sector, 'whereby distances may be taken to half minutes, and no difference found in the same observation often repeated, the instrument not being liable to any prejudice by warping or luxation.'

And last, but not least, he gave his valuable collection of astronomical and mathematical books to the Savilian Library of the University. They are stamped with his monogram and are mostly inscribed *Liber Bibliothecae Savilianae in Scoliis Publicis apud Oxon. ex dono viri Illustrissimi D. Christophori Wren*, 1673—the year when he submitted his first design for the new cathedral to the King.

It is almost certain that the needs of Astronomy were pointed out by Halley on his election to the Savilian Professorship in 1703.[2]

Edmund Halley (1656-1742) had been a Commoner of Queen's College, which he entered, aged 17, 'with such a knowledge of geometry as to make a complete dial.' And while at Queen's College he had observed

[1] *Principia*, Scholium to Prop. iv B 1.

[2] Of Gregory's lectures in this year there still exists a MS. *Lectio Astronomica habita in Schola Astronomiae in Vesperiis Comitiorum Academiae Oxon decimo die Julii Anni MDCCIII.* MS. in Christ Church Library.

WREN'S BOOKS STAMPED C. W.

Savilian Library

a sunspot in July and August, 1676, and an occultation of Mars.

The convenience, indeed, the necessity, of an observatory near the astronomer's house (or of an astronomer's house near his observatory) was obvious. The **second University Observatory** fulfilled this condition. Stable Hall at the end of the cloisters in New College Lane had been held on lease from New College by the Savilian Professor of Geometry, Dr. Wallis. In 1704 the lease was given by his son to the University, in order that the tenement might be appropriated to the use of the Savilian professors, and two letters to Dr. Charlett indicate that the house was repaired and that the observatory was erected in 1705. In March Dr. Gregory wrote, 'I hope Mr. Halley will prevail so far, as that the university will repair the house, and adding an observatory to the top of it will be very convenient and indeed useful to the university, and what Sir Henry Savile did expect from them, as you will see in sect. 2 of his statutes.'

Dr. Wallis's House, Stable Hall, New College Lane.
From Ingram, Memorials of Oxford. Block lent by Mr. Parker.

In June Halley expresses 'many thanks for repeated favours, as well in what relates to my house, wherein I must esteem you my great benefactor'. (Halley to Charlett, in *Letters written by eminent persons*, i, p. 139.)

We know but little of the equipment of Halley's observatory. He would doubtless have inherited the apparatus enumerated in the Savile list, and his more modern instruments would have resembled those of the Orrery collection preserved at Christ Church.

Perhaps his telescopic equipment was not so good as he would have wished, for he is known to have gone to London to the rooms of the Royal Society to observe the total eclipse of the sun in 1715—an early instance of an Eclipse Expedition, an outing that has been found to be so stimulating that no modern astronomer misses one if he can help it.

But lack of astronomical instruments was not unknown in the national observatories. Even the Royal Observatory at Greenwich in 1710 was 'worse furnished with instruments than we expected' (Uffenbach). In 1720 Halley, on succeeding Flamsteed as Astronomer Royal, found the observatory in a deplorable condition. There were no instruments there at all, nor anything else that was movable; for such things, being the private property of Flamsteed, had been removed by his widow. Halley acquired a Transit instrument and the 8-foot iron quadrant which is still there.

In Oxford, when KEILL died and JAMES BRADLEY of Balliol succeeded in 1721 as Savilian Professor of Astronomy, a new spirit was breathed into astronomical studies. His name will always remain famous as that of the discoverer of the aberration of light from the fixed stars (1727), the result of the limited velocity of light and the earth's annual motion. His success was due to his 'consummate practical skill in the use of astronomical instruments'. (Ball.)

But Oxford can hardly claim to have trained him in this matter. There were no instruments whatever of a kind suitable for his work. One can hardly imagine a greater deprivation to a keen astronomer like Bradley, who was a thoroughly practical man, who cleaned his clocks, and fitted up and repaired his own instruments. With the help of his uncle, Mr. Pound,[1] he had contrived a clock-driven telescope in 1719. As Rigaud has pointed out, his extraordinary skill in the management of ungainly telescopes is shown by his measure of the

[1] James Pound, 1669–1724, matric. St. Mary's Hall 1687, B.A. from Hart Hall 1694, M.B. 1697. Rector of Wanstead 1707. F.R.S. 1699, admitted 1713. 'Furnished with very curious instruments, and well skilled in the matter of observation', Halley, *Phil. Trans.* xxix. 252. *D.N.B.*

diameter of Venus in December 1722, with a telescope of 212¼ feet in length.

The loss to astronomical science due to the want of a properly equipped observatory in Oxford is well illustrated by the following episode. On 9th October 1723 Halley observed a comet. He immediately communicated the news to Bradley, who continued to observe it in his uncle's observatory at Wanstead until November 14, when 'his affairs called him to Oxford, where he had no convenience for continuing his observations'.

On Pound's death, Bradley succeeded to his instruments which appear to have been valued at £25 only. They included a transit, a reflector by Hadley, the 15-foot glass which was most used, a 7-foot glass, and a 10- or 11-foot glass, and 'Mr. Graham's instrument' (used from 1727 to 1731 for observing equal altitudes).

Observatory in New College Lane.

He had clearly not much spare cash for instruments in 1724. His professorship brought him only £138 5*s.* 9*d.* per annum, and his journeys backwards and forwards to his observatories at Wanstead and Kew[1] must have been an important item in his budget. In May 1732 Bradley removed to Oxford, and occupied the official residence in New College Lane which went with the Savilian Professorship; and to this abode he was accompanied by aunt and instruments from Wanstead.

Ingram notes in his *Memorials* that the New College Lane observatory was undoubtedly much used by Bradley, 'but he was from early youth accustomed to meridional observation, and would not have confined himself to four comparatively small apertures towards the four cardinal points, which in fact obliged him to

[1] In 1725 Samuel Molyneux had set up a 24-foot zenith telescope by Graham at Kew Green for observing γ Draconis.

set up his transit instrument in one of the back windows of the (Ashmolean) Museum'; the mark by which it was adjusted being the easternmost part of the lower ridge of the roof of All Saints Church in the High Street (17th February 1741). He also made use of his fifteen-foot telescope, though where is uncertain: there was no place for it in his small house or in the little court before it, and the Museum afforded no accommodation, for all the windows on the south side open either from the staircase or from very small rooms. (Rigaud.) This fifteen-foot glass was probably the same which he had used for observing Jupiter's satellites in June 1731 and the eclipse of the sun on December 6, 1732. In 1737 he observed a small comet at Oxford.[1] Many of his measurements were made with a micrometer applied to a good seven-foot tube. His experiences were often disheartening, for like all who strive after the utmost accuracy in observation, he was repeatedly hindered by unexpected troubles. Sometimes after only a short absence from Oxford, he would find on his return that the wall of the house, to which his instrument was attached, had fallen back a little.

In June 1742 Bradley went to reside at Greenwich, where he found the instruments in a wretched state.[2] He renovated the equipment by the purchase of a brass eight-foot mural quadrant by Bird, an eight-foot transit instrument, and an equatorial sector. These all remained in use until superseded by Troughton's instruments. He determined the longitude of Oxford as 5′ 0″ west of Greenwich.

A **fourth** Oxford observatory was established by N. Bliss, Rector of St. Ebbe's, when he succeeded Halley in the geometry chair. Being impressed with the need of stability, he fixed his instruments on a part of the city wall, which extended from his official house to the north-west angle of New College cloisters. The rampart of this part of the wall, which was cut away by Dr. Smith about 1768, was entire in the time of Bliss.

[1] 'Observations upon the Comet that appeared in the months of January, February, and March 1737, made at Oxford', *Phil. Trans.* xl.

[2] Charles Mason's letters to Dr. Hornsby.

His meridian mark was upon the buildings of All Souls College. He supplemented Bradley's work by observations of Jupiter's satellites.

Bradley, having died in 1762, was succeeded in the professorship by THOMAS HORNSBY, who had an observatory of his own at Corpus Christi College, of which College he was a Fellow.

Hornsby at once determined to furnish himself with instruments, though, as he put it, 'at an expense which I ought not to have in prudence incurred.' His small 32-inch quadrant alone cost £80. It was his intention that this quadrant and other small instruments should be set up at the Radcliffe Observatory, for the use of the class, 'by which those who desired astronomical training might observe at the same time that observations were being made with the larger instruments and thus judge of the degree of accuracy of their own observations.' Hornsby estimated that this might be done at a cost of £150.[1]

The 32-inch quadrant was fitted up in a small room, which though sufficient for observing was not large enough for more than three persons to have the manner of using the instrument explained to them at the same time.

It was at Corpus that he made his first determination of the latitude of Oxford with the mural quadrant. Two papers in the *Philosophical Transactions*, vol. lix, give some interesting particulars respecting the places where the transit of Venus was observed in Oxford on the evening of June 3, 1769.

		Instruments
Tower of the Schools	Dr. Hornsby	Transit, 12′ & 7½′ Rr.
Tower of New College	Mr. Lucas, New Coll. & Clare, Fell. of St. John's	6′ Rr.
A room in the Infirmary facing NW.	B. Nitikin, St. Mary Hall	10″ Rl.
	J. Williamson, St. Alb. Hall	8′ Rr.
Brasenose	Sir Christopher Sykes	3½′ Rr.
Balliol	Sir George Shuckburgh	
Christ Church	Samuel Horsley, F.R.S.	18″ Rl.
	Cyril Jackson, Ch. Ch.	9′ Rr.

Rl = Reflector: Rr = Refractor.

[1] Rigaud, *Note Book*.

THE RADCLIFFE OBSERVATORY

Telescopes and other astronomical instruments had now, both by reason of their size and by the necessity for firm foundations and fixed points of observation, led to the need of a proper observatory.

The circumstances of the foundation of the Radcliffe Observatory are described in a copy of a paper printed in 1771 of which the original was stated to be in the Common Room of Exeter College.[1]

'In the Summer of 1768 the Professor of Astronomy laid before the hebdomadal meeting a petition to the Earl of Litchfield and the Radcliffe Trustees for a grant for proper instruments and an Observatory. There is now only one person living who is capable of making them with that precision and accuracy on which the goodness of the observations essentially depends. He is between 50 and 60 years of age, and has been so much afflicted with the gravel for the seven months last past, that he cannot now bear the motion of a carriage, and for one half of his time has been confined to his house. It is much to be wished therefore that Mr. Bird might receive orders to set about the instruments without farther loss of time and while there is yet a probability of his living to execute them.

'The instruments which are essential to an Observatory, are a Transit Instrument, two Mural Quadrants, a Zenith Sector, and an Equatorial Sector: the price of which, as nearly as can now be computed, will be £1300. The three former cannot be finished before September 1773, and the two latter may probably be finished by the end of the following year. To these instruments, and to these only, Mr. Bird would dedicate his time upon the following conditions: viz. That £200 be immediately advanced to him, and that he be paid the sum of £100 at the expiration of every half year till the whole be finished. It is necessary that money should thus be advanced to him, as he proposes to employ himself and his journeymen upon the above instruments wholly . . . ; in case of death, the instruments, if unfinished are to be delivered to the University, . . . money was to be advanced

[1] S. P. Rigaud's *Note Book*, November 14, 1828.

by way of Loan from the Clarendon Press account, to be repaid by the Radcliffe Trustees.

'The Professor of Astronomy was desirous that Members of Convocation should be informed.

I. That as soon as the Observatory is finished, the Professor be employed in making a continued series of Observations, to be annually printed . . . and published. . . .

II. That a course of Lectures in Practical Astronomy be read by the Professor twice in every year, and proper Assistance given by him to all such members of the University, as are desirous to improve themselves in that branch of Science.

'In consideration therefore of the great advantages that may be derived to Mankind in general from Observations carefully made with such accurate instruments, and from the farther extension of Astronomical knowledge, and also of the Honour that will from thence redound to the University of Oxford in particular, the Savilian Professor of Astronomy, who has no other point in view than the promoting of these valuable Ends, and the prosecution of the Duties of his Office, agreeably to the intentions of his beneficent Founder is induced to hope for the Concurrence of the Members of Convocation in the same design. . . . (The letter ends with a quotation from the Savilian Statutes).

THOMAS HORNSBY,
Sav. Prof. of Astronomy.'

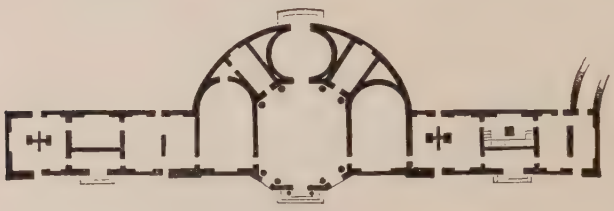
Oxford. Feb. 5. 1771.

The financial proposals involved were accepted by Convocation on the 5th February. The Duke of Marlborough contributed a lease of 8½ acres[1] which he held under St. John's College, affording a site which at the time was sufficiently removed from any surrounding buildings. The plans came before the Radcliffe Trustees on 20 March, 1773. The greater part of the building was finished by Mr. James Pears, under the direction of James Wyatt, and was roofed in in 1778. Hornsby was able to occupy his house in 1776. But owing to the dilatoriness of the architects employed, nearly a quarter

[1] The entire area was computed at 9 acres, 1 rood, 7 poles. Rigaud, *Note Book*.

of a century elapsed between the delivery of the first plans by Keene and the completion of the external sculpture and internal arrangements by James Wyatt in 1795.

The whole front has a length of 175 ft., the two wings extending 69 ft. east and west. The central tower is surmounted by a globe, supported by the bronze figures of Hercules and Atlas, the top of which is about 106 ft.



Ground Plan of the Radcliffe Observatory.

from the ground. A covered way leads from an adjoining dwelling-house for the observer to the eastern wing, as shown in the annexed plan.

Arrangement of Rooms and Instruments

Eastern Wing.
- Two Mural Quadrants of 8 ft. radius by Bird, 1772–3.
- Zenith Sector 12 ft. by Bird, 1772–3. In a north room.
- Transit Instrument ,, ,,
- Observer's Study.

Central Hall, 30 ft. in diameter, and Staircase.

Western Wing.
- Mural Quadrant by Bird, with which Hornsby made his first determination of the latitude of Oxford at Corpus. (*Phil. Trans.* lix.)
- Small transit by Bird. Used by Hornsby at Corpus.[1]
- 6-foot Circle by Jones of Charing Cross (not there in 1837).

On the First Floor:
- Lecture Room.
- Two apparatus rooms, now used for the Library.

[1] Hornsby had been admitted to C. C. C. in November 1749.

In the Upper Building:

10-foot Reflector by Sir Wm. Herschel.

$4\frac{1}{2}$-inch Refractor by Dollond, 10 ft. focus.

$3\frac{3}{4}$-inch ,, ,, $3\frac{1}{2}$ ft. focus.

These three instruments could either be used from the windows or be taken out on to the flat roof.

An equatorial of $2\frac{1}{2}$-inch aperture was housed in a separate building erected in 1774–6. This instrument had not been finished at the time of Bird's death, and so the Radcliffe Trustees determined to procure a new equatorial.

To Hornsby succeeded ABRAM ROBERTSON and STEPHEN RIGAUD; and when Rigaud died in 1839, the Radcliffe Trustees appointed MANUEL JOHNSON Radcliffe Observer. Since then this office has been separated from the Professorship.

On the 11th June, 1849, Professor Donkin asked for £200 worth of instruments for his class.

A highly important addition was made to the Radcliffe Observatory in 1850 by the acquisition of the 'best known' heliometer. The optical parts are by Merz of Munich and the mounting by Repsold of Hamburg. Objective $7\frac{1}{2}$ in. diameter and 10 ft. 4 in. focus.[1]

Although now well beyond the limits set to Early Astronomy in Oxford, we feel that we must mention the name of NORMAN ROBERT POGSON[2] (1829–91), who as Assistant at the Radcliffe Observatory (1852–9) discovered four minor planets and did valuable work on variable stars. 'In the use of the equatorial and meridian circle he had few equals.' *D. N. B.*

DISTRIBUTION OF ENGLISH-MADE INSTRUMENTS IN BRITAIN AND ON THE CONTINENT

End of eighteenth century to *c.* 1830

As the result of the provision of excellent instruments by the leading English makers, and of the splendid discoveries of W. Herschel and others, and the alluring prospect of further similar discoveries in the heavens,

[1] Cf. *Radcliffe Observations*, vol. xi; Chambers, *Handbook*, pl. xxiv.

[2] Director of Hartwell Observatory 1859 60, Govt. Astronomer at Madras, 1861–91.

the period of 1820-30 was one when astronomy was cultivated both in Great Britain and in the countries of Europe with an ardour that has been surpassed at no earlier period.

The following were the principal instruments at Greenwich about 1830:

Instrument	*Maker*
8-foot Transit (used by Halley, Bradley, and Maskelyne).	Bird, improved by Dollond and Troughton.
8-foot Mural Quadrants.	Bird and Graham.
Zenith Sector, used at Kew by Bradley.	
40-inch Achromatic Triplet.	Dollond.
5-foot Achromatic.	Dollond.
6-foot Reflector.	Sir Wm. Herschel.
Equatorial Sector.	Sisson.
A dry Well, 100 ft. deep.*	(Designed, but never constructed.)

Other observatories were established at the following places:

Richmond, built in 1768 under the direction of Dr. Demainbray by order of George III, who is said to have witnessed there the transit of Venus in 1769.

Equipment: Transit Instrument.
Zenith Sector.
Mural Quadrant.
A superb Equatorial.
10-foot reflector of Sir Wm. Herschel.

Oxford, 1772.
Dunsink near Dublin, 1785.
Armagh, 1790.
Edinburgh, 1811.
Royal Society at Somerset House.
Cambridge, 1823. Trin. Coll. Obs. 1706–1792.
Portsmouth Royal Naval College.
Christ's Hospital.

A proof of the activity of the time is not only to be sought in the perfection of the great public observatories, but is also evident from the number and excellence of private observations made in private observatories. In the year 1830 there

* Prof. H. Turner has shown me a unique print, 25 inches long, of Flamsteed's well in an album of early views of Greenwich Observatory.

were in this country English instruments of good quality at the following places:

Bedford	belonging to	Captain Smyth, 1830
Blenheim	,,	Duke of Marlborough
Blackheath	,,	Stephen Groombridge, 1806
,,	,,	Lord Wrottesley
Cambridge	,,	Rev. M. Catton
Chislehurst	,,	Rev. Francis Wollaston
*Derby	,,	William Strutt
East Sheen	,,	Rev. William Pearson
Finsbury Square	,,	Dr. Kelly
Goodwood	,,	Duke of Richmond
Gosport	,,	Dr. William Burney
Hackney Wick	,,	Colonel Beaufoy
*Hayes	,,	William Walker
*Highbury Terrace	,,	Captain Huddart
*Hoddesdon	,,	William Hodgson
*Islington	,,	Gavin Lowe
Ormskirk	,,	Rev. W. R. Dawes, 1830
*Paragon, Southwark	,,	James Strode Butt
*Park Lane	,,	Sir H. Englefield, Bart., †1822
*Rose Hill, Sussex	,,	John Fuller
Shirburn	,,	Earl of Macclesfield[1]
Slough, 1786	,,	Sir W. Herschel
Southwark	,,	Sir James South, 1816–24
*St. Ibbs, Hitchin	,,	Professor Lax
Woolwich	,,	Royal Military Academy

The following list presents some idea of the wide distribution of the masterpieces of the English instrument makers among the Observatories of Europe in the period 1800–1830.

France

Paris.
- Royal Observatory, 1667, enlarged 1788, with Transit and Circle by Ramsden.
- Monnier's, 1742.
- Marine, 1748.
- Mazarin College.
- Palace of Luxembourg.
- Abbey of St. Geneviève, 1756.
- Cagnoli's, 1785.
- Military School, 1768, fitted in 1774 with 8-foot Quadrant by Bird.
- Royal College, 1775.

Paris. Geoffroy d'Assy's, 1788.
Marseilles.
Toulouse.
Lyons.
*Dijon, 1780.
Montpellier.
Béziers.
*Avignon, 1683.
*Strasbourg.
Bordeaux.
Brest.
*Rouen.
Montauban before 1769.

* = of minor importance.

[1] In 1769 Lord Macclesfield's $3\frac{1}{2}$-, 6-, and 14-foot refractors were used to observe the Transit of Venus (*Phil. Trans.* lix).

Italy

Roman College, 1787.
  Ramsden and Dollond.
Bologna, 1714.
Pisa, 1730.
  Sisson, Short, Graham.
Milan, 1765.
  English instruments.
Florence, 1772.
  Ramsden, 1786.
Turin, 1790.
Venice.
Verona, 1787.
Padua, 1767.
  Ramsden, 1778.
Naples, 1812.
*Malta, 1783.
Palermo, 1790.
  Transit and Circle by Ramsden.

Germany

Berlin, 1711.
Königsberg, 1813.
Vienna University, 1755.
  ,, College of Jesuits, 1735.
Göttingen, 1751.
Mannheim, 1772.
  8-foot mural quadrant by Bird.
  6-foot transit by Ramsden.
Nuremberg, 1678.
  ,, and another, 1692.
*Cassel, 1714.
*Giessen, 1740.
Leipzig, 1788.
Bremen. Olbers obs.
Lilienthal, 1786.
Seeberg near Gotha, 1788.
  Transit, two 8-foot mural quadrants, Circle, 8-foot diameter, by Ramsden.
*Brunswick.
*Danzig. (Obs. of Hevelius.)

Holland and Denmark

Copenhagen, 1656.
University of Holland, 1690.
Leyden.
Utrecht, 1726.
Altona, 1823.

Spain and Portugal

Madrid.
Cadiz.
  English Instruments.
*Seville.
*Cartagena.
Lisbon, 1728.
  ,, 1787.
Coimbra, 1792.
  Equatorial by Troughton.

Sweden

Wilna, 1753. Ramsden.
Stockholm, 1746. English instruments.
Upsala, 1739.

Russia

Petersburg, 1725. Peter the Great.
Moscow, 1825. Cary's instruments were mostly destroyed in fire.

* = of minor importance.

Magdalen College Observatory

In March 1855 Professor Charles Daubeny presented a fine equatorially-mounted **Refracting Telescope** of 5½-inch aperture by Cooke to the College. In December

1856 a substantial vaulted structure was erected for it 'contiguous to the wall of the Botanic Garden, according to the plan of Mr. Buckler, at an estimate of £185'. The possession of such an instrument was greatly valued by successive generations of Science Tutors of the College, and T. H. T. Hopkins, Edward Chapman, and the present author have all found it of great value for showing to undergraduate members of the College some few of the more readily observed celestial objects. It is surprising how many persons who pose as 'well educated' have never looked through a telescope. A more extended use of the instrument has been made by W. Newbold, F.R.A.S., and by Professor H. Hilton, on Variable Stars.

The University Observatory

By the election of Charles Pritchard to the Savilian Chair in 1870 in succession to William Fishburn Donkin, Oxford again acquired a practical astronomer as Professor, but in consequence of an unwise policy in the past had neither observatory nor instruments to offer him. The new Professor's first efforts were therefore directed to the foundation of a 'Department'. Starting with the few simple instruments that he had acquired for his own use and for showing to his boys when head master of Clapham Grammar School, he died leaving the University equipped with instruments and an observatory which have enabled her to take an honourable place in the greatest work of modern astronomy, the systematic International Photographic Astrographic Survey of the Heavens.

In consequence of the representations of Professor Pritchard, Convocation in March 1873 voted the sum of £2,500 and a site in the Parks for an astronomical observatory and for a 12¼-inch refracting telescope by Howard Grubb of Dublin.

The young observatory was further enriched in 1874 by the noble gift from Dr. Warren de la Rue of his far-famed reflector and of all his instruments at Cranford which, as he said, 'were constructed from his own drawings, and by the hands of his own engineers.'

All seems to have gone off well, and by November 1875 Professor Pritchard was able to describe the com-

pletion of the building, and the installation of the instruments in the **New Savilian Observatory for Astronomical Physics**.[1] The Observatory buildings included a West Dome for the Grubb Refractor, an East or De la Rue Dome for the De la Rue Reflector; between the two domes were (1) De la Rue's 13-in. Reflector mounted as an altazimuth, (2) a 5-inch Transit, and (3) certain small educational instruments for students. On the left of the entrance are the Library and Lecture Room. In the basement are De la Rue's polishing machine for the telescope mirrors and Foucault's apparatus for testing figures.

It has not unfrequently been stated, especially by German writers, that the centre for the manufacture of great telescopes at this time was Munich, but this is not correct, it was in Dublin.

During Pritchard's life the observatory and its instruments were chiefly employed for stellar photography, wedge-photometry, and the measurement of stellar parallax.[2]

Wren's note on Bishop Fell's proposed Observatory on Tom Tower, 1681. See p. 392.

[1] *Monthly Notices*, xxxiv. 49; xxxv. 376; xxxvi. 1.

[2] Charles Pritchard's Biography in the *D.N.B.*; *Report on the Capacities in respect of Light of two Silver Glass Mirrors*, P.R.S., xli. 195.

SUNDIALS

Here did Wren make himself a student home

. . . . . .

I wonder if this straying shadow moves
Adown the wall as then he saw it roam. A. Upson, 1900.

ISAIAH (xxxvii. 8) was the first to record a sundial, but long before the days of Ahaz, *c.* 700 B.C., man must have been familiar with various methods of estimating the time of day by the movement of shadows. The objects chosen for casting shadows were given various shapes. A bead or small ball was fixed in the centre of the hemicyclic sundial of Berosus about 300 B.C., which was the prototype of the Roman sundials, but the gnomon, or style fixed parallel to the axis of the earth, can boast a yet greater antiquity, for Herodotus states that the Greeks 'learnt concerning the pole, the gnomon and the twelve parts of the day from the Babylonians'.[1]

The merit of having introduced the oriental sundial into Greece is due to Anaximander (born *c.* 610 B.C.), whose instrument is said to have shown the times, the equinoxes, the seasons, and the solstices.[2] In the far east the Chinese are said to have used the gnomon for measuring the obliquity of the ecliptic as early as 1100 B.C.

The gnomon in its simplest form consisted of an upright rod stuck in the ground, the shadow of which was then observed. The surface of the ground was flattened and levelled until water poured on it ran off equally on every side.[3] A circle was then described with the rod as centre, and with a radius rather greater than the shadow of the rod at its shortest; so that the end of the shadow would cross the circle before and after mid-day. These two crossing-points were joined with a line which, bisected, indicated the meridian. When mankind discovered the advantage of inclining the gnomon to the angle equal to the latitude of the place, the first step towards the construction of a sundial was made.

[1] Herodotus, ii. 109.
[2] Eusebius, *Praep. Evang.*, x. 14. 11.
[3] Sédillot, *Mémoire.*

The first description of a dial in England is given us by BEDE, and there are a few mural dials of Saxon age upon churches in various parts of England. We do not know of any of these very early dials in the vicinity of Oxford, but good representative examples are to be seen at Daglingworth and Saintbury in Gloucestershire. In these Saxon dials the 12 day-hours are divided into four tides of 3 hours each. The gnomon was usually a wooden peg fixed in the stylehole so as to project perpendicularly to the surface of the wall.

Saxon dials were as a rule of good and careful workmanship. They were superseded when the architectural style became Norman, and when the plan of dividing the day into the four tides got to be out of date and the new method of reckoning time had come in. Successive church rebuildings and restorations destroyed the majority of the old Saxon dials.

Their place was taken by the less perfect instruments, known as **Mass dials** or **Scratch dials,** of which Horne[1] has enumerated several types. We have found several upon the walls of churches near Oxford. In point of workmanship they are much rougher than the Saxon dials—many are marked merely with one or two hour lines radiating from a central hole. They are, therefore, to be regarded less as complete clocks than as indicators of particular hours—as mass-markers rather than as time-tellers.

A peg fixed in the central hole and standing out at right angles to the face of the wall formed the gnomon or style. In many cases the noon line is not quite vertically below the stylehole—indicating that the dial maker had fixed the gnomon first and had then marked the position of its shadow at noon. On the right and left are lines at right angles to the noon line, denoting 6 a.m. and 6 p.m. and nearly half-way between the 6 a.m. and the noon line is one that marks 9 a.m. This is the mass line, for which the dials were specially constructed.

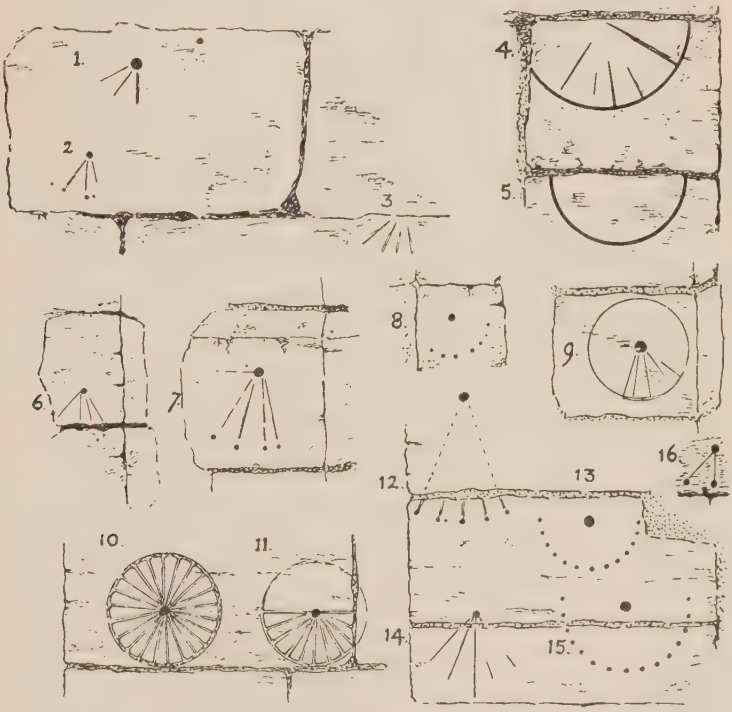
Mass dials of the following types have been distinguished, and it is satisfactory to note that more than half of these types are still to be found on the south walls of churches within a few miles of Oxford.

[1] E. Horne, *Primitive Sundials*, Taunton, 1917.

A.

1. Stylehole in a joint between two courses of masonry, with lateral and perpendicular joints serving as lines, additional incised lines being added.
2. Stylehole in a joint between two courses of masonry, with all the lines incised and no joints used.

BEGBROKE.



SCRATCH DIALS ON CHURCHES NEAR OXFORD.

1–3. Cumnor.	4, 5. Begbroke.	6. N. Hincksey.
7. Binsey.	8. Eynsham.	9. Yarnton.
10–11. Elsfield.	12–15. Kidlington.	16. Binsey.

B.

3. Stylehole made in a stone, with lines radiating from it downwards only.

NORTH HINCKSEY, KIDLINGTON.

The commonest form.

4. Stylehole made in a stone, with lines radiating from it in all directions.
5. Stylehole made in a stone, with the radiating lines enclosed in (*a*) a portion of a circle, (*b*) a semicircle, (*c*) a complete circle. ELSFIELD.
6. Mass dial with 2 or 3 very short wedge-shaped lines beneath the stylehole, having their points towards the style.
7. Mass dial with a perpendicular and a horizontal line cutting across the stylehole. In one or more of the 4 right angles thus formed, one or more radiating lines. BINSEY and ? S. HINCKSEY.
8. As 7, but the whole contained in a circle. (Probably a Saxon sundial, or a copy of one.)
9. An arc or semicircle of holes at a short distance from the stylehole. The holes probably held pegs. EYNSHAM, KIDLINGTON, S. HINCKSEY.
10. Stylehole surrounded by a complete circle of holes.
11. With holes drilled at the ends of radiating hour lines. CUMNOR.
12. Dial circles or semicircles having no incised hour lines or holes. Possibly hour lines were painted on the surface of the stone.
BEGBROKE, S. HINCKSEY.

Horne offers the reasonable suggestion that these dials first came into use at a period after the Saxon sundials had gone out of use and before clocks had become common as time-keepers. On many a church wall they lingered on until they were superseded by the more scientific mural sundial with its inclined gnomon and its more complete set of hour lines all marked by figures. The mass dial had a horizontal gnomon, at right angles to the surface of the stone, and it never had figures to indicate hours. Sundials were made for the twelve hours of the day; mass dials only show particular hours.

We have described these rude instruments at some length in the hope of drawing public attention to them. They were no doubt once widely distributed on the walls of churches and monasteries. I was first told about them by my pupil Mr. Williams who informed me that

he had also recognized mass dials on the churches of Cassington and Marsh Baldon, but we have no very early dials in Oxford itself. It is indeed remarkable that so many should have survived in the county.

We quote Horne's concluding sentence: 'Scratch dials are few and feeble now, for the wind and storms of five or six centuries have nearly worn them out, but the remnant seemed worth saving for the sake of the story that they tell.'

Dials of the Sixteenth and Seventeenth Centuries

During the sixteenth century there had been a great revival of gnomonic lore in Southern Germany and many treatises on the subject were published. Among the early authorities was our Oxford Reader, Nicholas Kratzer, whose Latin manuscript may be seen in the library of Corpus Christi College, but the dials he set up have been allowed to moulder away. Some idea of his work may be obtained from a small portable dial made by him for Cardinal Wolsey, and now in the collection of Mr. Lewis Evans. A story illustrating his merry spirit is repeated in the *Book of Sundials.* When Henry VIII asked him how it was that after so many years in England he had not learned to speak the language, he replied: 'Pardon, your highness, but how can a man learn English in only thirty years?' His portrait, one of Holbein's finest works, is in the Louvre.

Many types of dials were described by his contemporary, Sebastian Munster; and when Clavius' great work had appeared, *Gnomonices de horologiis*, 1581–1612, all that was then known about dialling was in the hands of the public, and helped to foster the popular interest. The first book in English appeared in 1593. It was a translation of the work of Witikind by Thomas Fale, and was entitled *Horologiographica, the Art of Dialling, teaching an easie and perfect way to make all kinds of Dials upon any plaine plat, howsoever placed, with the drawing of the twelve Signes, and houres unequall in them all.* In his preface Fale refers to Recorde and Digges of Oxford as persons, 'who if they would take the paines', could write of the science of Dialling 'with great commenda-

tion'. Fale's work acted as an incentive to people of all conditions to erect instruments that would tell the time.

Dials were set up in the King's Privy Garden at Whitehall (MS. Ashmole 350) which were so highly thought of, that in 1624 EDMUND GUNTER of Christ Church, Professor of Astronomy at Gresham College, was commissioned to write a description of them.

In the preface to his *Description and Vse of His Majesties Dials in Whitehall* Gunter humbly entreats his Majesty 'to accept these poore fruits of my younger Studies, when I was Your Maiestie's Scholler in Westminster and Christchurch: and I shall be ready to doe all services in this kinde or better in the Church; as Your Maiesty shall be pleased to think me worthy'. He concludes by stating that 'These and such like are the uses of these Dials: if too obscurely delivered, your Maiestie may command the Author'.

The interest of Charles I in the subject never flagged. He constantly carried about with him a small silver mathematical ring, a dial, of a construction invented by M. Delamain[1] which he much valued, and the night before his execution he gave it to his attendant Herbert in charge for the Duke of York. (Gatty.)

The names of many Oxford men are connected with Dials and Dialling. We will here but mention the names of WREN, whose dial at All Souls College is described on p. 113, and of EDMUND HALLEY, who is quoted as an authority by John Holwell, 'These 3 Ways [of how to draw the Parallels in Dialling] I had given me by my very Loving Friend Mr. Edmund Halley of Queens College in Oxford.'[2]

The sundial must, however, always be regarded with the interest that attaches to an exotic product. It had its birth in regions where the average temperature is 70°. There it grew to gigantic proportions, 20-30 or more feet in length, and in Samarkand Ulugh Beg's dial (1437) had a gnomon of 180 feet in length. In this cold and comparatively sunless climate it has hardly managed

[1] Delamain was the author of *The making, description and use of a small portable instrument for the pocket, in form of a mixt Traperzia, thus called a Horizontal Quadrant*, with plates, curious woodcuts, and a folding table for making the quadrant, 1631.

[2] Holwell, *Clavis Horologiae*, 1686, pp. 285-7.

NICHOLAS KRATZER OF C. C. C., 1528

After the painting by Holbein in the Louvre

Three of the dials shown also figure in Holbein's Ambassadors in the National Gallery

to survive except as a garden ornament. Our mural dials on College walls have mostly perished with the stone on which they were carved or have been obliterated in the course of architects' 'restorations'.

PEDESTAL DIALS

Detached Vertical Sundial. 1520.

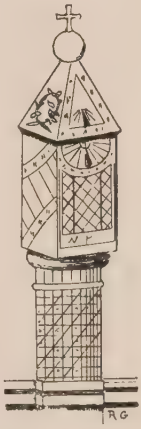
By Nicholas Kratzer.

On the Churchyard Wall of St. Mary's Church.

Removed 1744.

Loggan's engraving shows it to have been a cubical stone with dials on its 4 sides, supported on a pillar and surmounted by a pyramid with a ball and cross.

Kratzer gives the following account of himself and his dial in the MS. 'de Horologiis'.



KRATZER'S DIAL, ST. MARY'S CHURCH.
After Loggan.

'Anno 1520 Ego Nicolaus Krasterus bavarus monacensis natus servus regys Henricy viij jussu illius per-legi Oxoniae Astronomiam suplē spheram materialem Johannis de Sacro Bosco et compositionem astrolaby et geographiā Pthoł, in illo tempore erexi columnam seu cilindrum ante ecclesiam Diui Virginis cum lapicida Wilhemo East servo regis. Eo tempore Lutherus fuit ab-universitate condemnatus cuius testimonium ego Nicolaus Krasterus in columna manu propria scripta posui.

['In the year 1520, I, Nicolas Kratzer, born a Bavarian of Munich, a servant of King Henry VIII, at his command lectured at Oxford on Astronomy[1] and the supplement to Astronomy, the mundane sphere of John of Holywood, the composition of the Astrolabe and the geography of Ptolemy. While there I set up a column or cylinder before the church of the Blessed Virgin with the help of the mason William East, the king's servant. At that time Luther was condemned by the University, a testimony of which I Nicholas Kratzer wrote and placed with my own hand upon the column.']

[1] During the Presidency of Claymond (1516–37).

A further inscription in Latin[1] that was supposed to have been stuck up on the dial has been translated thus:

'To one thousand five hundred and three years add ten twice, and you will discover the time at which I was placed here. Thomas Mosgrave (then) professed medicine at Oxford, and was skilled therein. William East the stone cutter set me up fairly with his own hands, and placed me in this spot. Nicolas Kratzer, the Bavarian who was of Munich, caused me to tell all the hours. He also at that time lectured to his pupils on astronomy, and much learning he handed down. He was then the astronomer of King Henry, of that name the eighth, who held him very dear. The stone cutter was English, the other German, at the time when I was the admiration of the whole age. Both men drank ever in the German fashion, and could swallow all the liquor that there was.'

Then followed a set of verses[2] written by Ludovicus

[1] Annis mille tribus quingentique adde decem bis
invenies tempus quo hic situatus eram,
Oxonie rector Thomas Mosgrave medicinam
qui profitebatur quique peritus erat.
Me posuit lapicida suis Gulielmus Aestus.
perpulchre manibus, hunc dedit atque locum,
Nicolaus cunctas Krasterus bavarus horas
dicere me fecit qui monacensis erat,
Quique suis illo prelegerat astronomiam
tempore discipulis multaque tradiderat,
Et fuit Henrici tum octavi nominis huius
astronomus regis cui bene carus erat;
Anglus erat lapicida, fuit Germanus et alter,
totius aetatis cum decus ipse fui;
Ambo viri semper Germano more bibebant,
et poterant potus sugere quicquid erat.
Anno Dni 1520.

[2] *Carmina inscripta in horologio Vniversitatis Oxoniensium edita per Ludovicum Viuum:*

Ad orientem
Per Virgas Virides notantur horae
Quas monstrant numeri à die renato
Ad meridiem
Solis meatus lucis alternas Vices
Horas diurnas, signa, quae tempus notant,
Vmbrae docebunt Gnomonum meatis suis
Ad occidentem
Ceruleae signant ex quo se condidit undis
Temporis interea quot sol confecerit horas.
Ad septentrionem
Tempora, et obliqui solis lunaeque meatus
Ostendi mirum possunt mortalibus umbris.
MS. De Horologiis. MS. Corpus Christi Coll.

Vives in explanation of the use of the coloured and other lines on the four sides of the dial.

On the East: The hours are marked by green lines, which the numbers point out, beginning with the birth of the day. [= old German or Babylonian hours.]

On the South: The sun's journeys, the alternations of the light, the hours of the day, and the signs which mark the season, the shadows of the gnomons shall teach thee by their wanderings.

On the West: The dark blue lines show how many hours of time the sun hath fulfilled since he hid himself beneath the waters. [= the Italian hours.]

On the North: The times and the oblique movements of the sun and moon, can be shown forth, a miracle to mortal shades.

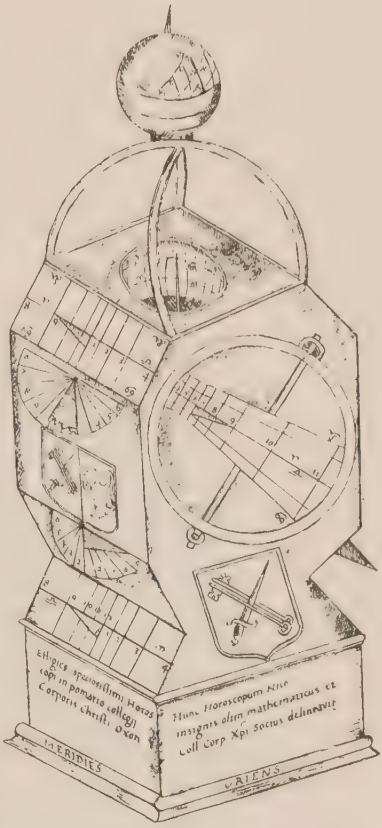
Polyhedral Dial.

1520–30.

Corpus Christi College Garden.

By Nicholas Kratzer.

The original has long since disappeared, but a sketch of it was made by Robert Hegge, scholar of C.C.C. in 1614 and a 'prodigy of his time' (Wood), who thus described the dial:



KRATZER'S DIAL, 1520–30.
After Hegge.

'In this beautiful Alter (on wch Art has Sacrificed such varietie of Invention to the Deitie of the Sun) are 12

Gnomons, the Sun's fellow travellers, who like farr distant inhabitants, dwell some under ye Aequinoctiall, some vnder the Poles, some in more temparat Climats, some vpon the plains in Plano, some vpon the Mountains in Convexo, and some in the valleys in Concavo. Here you may see the Aequinoctial dial the Mother of ye rest, who hath the horizons of the paralel Sphere for her dubble Province, which suffer by course an half year's night: There the Polar dial wing'd with the lateral Meridian. Here you may behold the two fac'd Vertical dial which shakes hands with both Poles: There the Convex dial elevated in triumph vpon 4 iron arches: Here lastly the Concave dial which shews the Sun at noone the hemisphere of Night. In other dials neighbouring Clocks betray their errours, but in this consort of Dials informed with one Soul of Art, they move all with one motion: and vnite with their stiles the prayse of the Artificer.—(Hegge, MS. *Treatise of Dials, c.* 1625–30.)

The dial was still standing in the garden in the time of Baskerville,[1] *c.* 1668.

Portable Polyhedral Dial. 1518–30.

L. Evans collection.

Almost certainly made for Cardinal Wolsey by Nicholas Kratzer.

The instrument consists of nine dials arranged on a block of gilt brass in a manner that has been described by L. Evans.[2] On each of the sloping base-plates is engraved a cardinal's hat, and on either side are the arms of Wolsey and of the cathedral church of York.

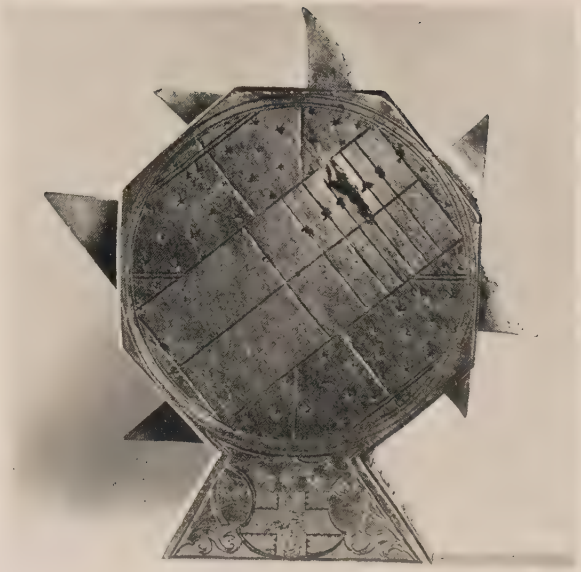
The identification of an early Fellow of Corpus as the maker rests on the very close resemblance between Wolsey's dial and the drawing of a dial by him; also on the circumstance that Kratzer, 'who had been reading Astronomy in the University by the command of K. Henry VIII, was soon after made by Cardinal Wolsey his Mathematick Reader, when he first settled his lectures there'.[3]

17. Column of Dials. 1581.

Quadrangle of Corpus Christi College.

By Charles Turnbull, author of a *Treatise on the Use of the Celestial Globe*, 1573.

[1] Rawlinson Misc. MSS. D 810.
[2] *Archaeologia*, lvii, 1901.
[3] Wood, *Athenae Oxonienses*.



SUNDIAL MADE FOR CARDINAL WOLSEY BY N. KRATZER

Lewis Evans collection

COPY OF TURNBULL'S DIAL AT PRINCETON UNIVERSITY

The principal dials are cut on the 4 sides of a rectangular block of stone supported on a column, and surmounted by a pyramid with four other dials on the slopes. On the top of all is a pelican standing upon an armillary sphere.

The vertical dials are partly covered by the four coats of arms carved in relief of Bishop Fox (south), Bishop Oldham (west), University of Oxford (north), and the King (east). The lower part of the scroll-work frame round each shield acts as a gnomon to the dial face engraved below it, a feature that was specially mentioned by Uffenbach who visited the College in 1710.

On the cornice above the shields are four Corpus Christi College mottoes:

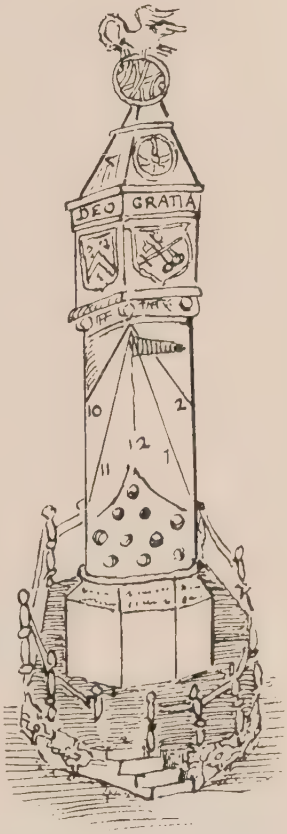
1581

Est deo gratia (south).

Gratia dei mecum (west).

Est reposita justitiae corona (north).

Posui deum adjutorem meum (east).



TURNBULL'S DIAL, 1581.
After Hegge, 1625–30.

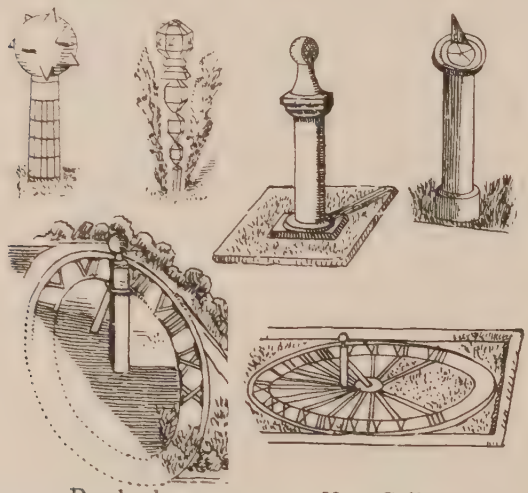
On the cylindrical shaft there is a ninth dial face,[1] with a perpetual calendar engraved below it, and nearer the base another motto—*Horas omnes complector.* This, as is indicated by the inscription, $\frac{\text{C T}}{\text{MD CV}}$, was probably added in 1605.

The entire column has recently been admirably restored by Mr. W. W. Fisher.

[1] Plot attributed the cylindrical dial to Robert Heggs (*sic*) and noted that all the hour circles except the meridian circles are ellipses.

A scale of degrees was marked below the gnomon on the column as indicated by an inscription stating that 'When Phoebus or the moon touch the midday mark the style will show you the space which you will say there is between it (Phoebus or the moon) and the zenith, the poles, and the horizon'.

Of the Pedestal Dials that were still in existence at the end of the seventeenth century, Loggan's accurate



PEDESTAL AND FLORAL DIALS, 1675.
After Loggan.

plates are the only surviving records of several that stood in perfect harmony with the formal gardens then in vogue. Oxford is the poorer by their disappearance.

TRINITY COLLEGE. **1675.**

a. A pillar carved as a pile of three geometrical solids, the many faces of which were doubtless used as dials, stood in a small garden in the south-west angle of the College land.

b. A globe with gnomons stood in the President's garden on the east side of the Library Quadrangle.

These two sundials may have been the handiwork of the resourceful Francis Potter who 'was smyth and joyner enough to serve his turne', who inhabited a 'chamber at Trin. Coll. which was the senior fellowe's chamber then (he lay with his brother, Dr. Hannibal Potter): this chamber is now united to the President's lodgeings'.[1]

St. John's College. 1675.

According to Loggan's print of the College a sundial appears to have stood near the middle of the north-east part of the garden.

Wadham College. c. 1654.

A 'variety of dials' were combined with Dr. Wilkins' transparent apiaries, 'built like castles and palaces'. (Evelyn's *Diary*, i, p. 271.)

Globe Dials

Balliol College. c. 1675.

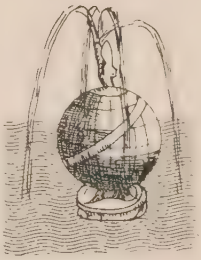
A globe on a column in the centre of a walled-in garden on the site of the present Master's Lodgings. (Loggan.)

Queen's College. c. 1675.

A globe on a column in a garden opposite St. Edmund Hall. (Loggan.)

Christ Church. 1670–95.

'A large globe covered with lead and gilt' formed the centrepiece of 'the circular bason of water' that had been constructed in 1670 by Dr. Richard Gardiner.[2] On 7th November 1695 the globe was displaced by a statue of Mercury presented by Antony Radcliffe, canon, from which the fountain pond took its present name. The globe was figured by Loggan in 1675.



Christ Church.

Wadham College. c. 1653–1753.

The great globe carried upon the shoulders of Atlas was probably the design of the ingenious Dr. Wilkins

[1] Aubrey, *Lives*. [2] As a votive offering for his escape from a fire. The Dean and Chapter covenanted to keep it in repair.

and may have been graduated as a globe-dial. It is well seen in the prints of Loggan (1688) and of Williams (1733). Atlas was 'blown down by the High wind, and broke all to pieces' in 1753, having stood for just a century.

Horizontal Sundials

Horizontal Sundial. 1579.

Base 7 inches square. Evans Coll.

By *H. Cole + + 1579 + for + Sur + Henry + d'arcy +* See vol. i, p. 173.

18. Horizontal Sundial. 1637.

Base 6 inches square. Ashmolean Museum.

H. Sutton fecit 1637.

Horizontal Dial on a Column. c. 1730.

Wadham College.

This is represented in Williams' *Oxonia depicta*, 1733, as standing near the north wall of the Fellows' Garden, but as it is not shown by Loggan we conclude that it was erected after 1688—perhaps just before 1730 when *causless and expensive alteracons in ye Garden* were made. (Wadham College, *Convention Book*, 1730.)

19. Horizontal Sundial. ? 1702.

Near the Clerk of Peace's Office.

Bearing the arms of Thomas, Earl of Wharton, Lord Lieutenant of Oxfordshire 1691–1702.

Motto:

Minutae sunt quae spectas, non quae perdis.

20. Horizontal Sundial. Early 19th cent.

Octagonal base, 5 inches across. Merton College.

On a window-sill on the first floor on the west side of, but outside the Fellows' Quadrangle.

The dial has been in this situation longer than the tenancy of Dr. Watts, the present occupant of the rooms.

21. Horizontal Sundial. 18—.

Base 4 inches square. Pitt-Rivers Museum.

22. Horizontal Sundial. ? 1840.

Diameter of base 9 inches. Botanic Gardens.

By 'Scott, London'.

Mounted on a basaltic column brought by Dr. Daubeny from the Giant's Causeway. (Gunther, *Oxford Gardens*, p. 60.)

Floral Dials

New College. 1688–1733.

A large horizontal dial was laid out in clipped box-trees marked with hour lines from IIII a.m. to VIII p.m. Where the hour numbers did not complete the circle, were the words SIC VITA, also in box. This floral dial lay on the west side of Mount Parnassus in the Garden, and next it was an elaborate piece of carpet bedding representing the coats of arms of the College and of England. It was seen by Uffenbach in August 1710. See fig. on p. 108.

It is reminiscent of Tycho's little hill 'representing Parnassus, the Mount of the Muses', on the middle of which stood a small statue of Mercury in brass turning round by a mechanism in the pedestal. (Dreyer, *Tycho*, p. 105.)

Pembroke College. Figured by Loggan, 1675.

A floral dial in the Garden to the north of the bowling green. It was not unlike the one at New College. See fig. on p. 108.

MURAL OR VERTICAL SUNDIALS

For those who live in houses and are also gifted with good powers of observation, the length of shadows or the direction in which sunbeams cross particular rooms are rough indications of the time of day. We knew a certain sexton in Shetland who used to ring for service as soon as he saw the sunbeams glint along the wall of his church. Orientated buildings certainly provided man with an indication of the time that was sufficiently reliable before the days of time-tables.

During the seventeenth century vertical sundials were more abundant on the walls of the Colleges of Oxford than is generally supposed, but as a consequence of the gradual improvement of clocks and watches, so

that they surpass the sun in regularity, our sundials have been neglected. Modern punctuality, in making itself independent of the sun, has caused the disappearance of an architectural feature, which appropriately treated was often an object of beauty and interest—praise which can rarely be bestowed upon the dial of the public clock. Although some have been repaired from time to time, the last traces of the greater number have been removed during one of the periodical refacings of the walls.

A list of mural dials in Colleges is given in the chronological order of the foundation of the Colleges, though not necessarily of the age of the dials; it is to be hoped that future search among papers and accounts may throw more light upon the subject.

List of Mural Dials in Oxford

Dials facing South

Balliol College.

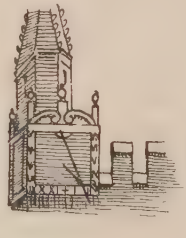
a. Figured by Loggan in 1675, and also by Williams in 1733.

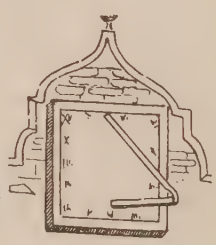
Against the battlements over the south side of the Chapel.

b. Figured by Loggan in 1675.

On the top of the Garden wall.

Balliol.





Oriel.

Exeter College. Figured by Loggan in 1675.

On the tower near the Rector's Lodgings.

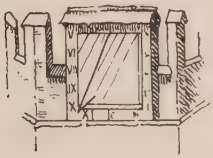
Oriel College. Figured by Williams in 1733.

Under the middle gable on the north side of the front quadrangle.

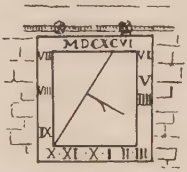
WREN'S DIAL AT ALL SOULS COLLEGE, C. 1640

QUEEN'S COLLEGE. Figured by Loggan in 1673.

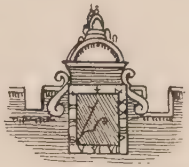
Over the bow window of the Provost's Lodgings.



QUEEN'S.



NEW COLLEGE.



CORPUS.

Dials facing South.

NEW COLLEGE. **Dated 1696.**

Against the end of the Hall. It is shown by Williams *c.* 1730, and twice in the *Oxford Almanack* for 1729.

ALL SOULS CHAPEL. **After 1653.**

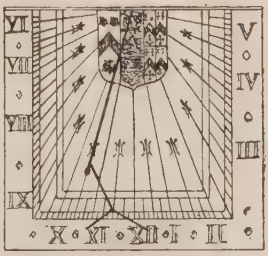
23. *a.* A large painted dial designed by Sir Christopher Wren soon after 1653 when he was elected to a Fellowship of the College. It was contrived by Wren so that 'one may see to a minute what it is a clock, the minutes being depicted on the sides of the rays, viz., 15 on each side, and divided into fives by a different character from the rest.' (Plot.)

It has been moved to the south wall of the Library where it now stands in good repair. The motto *Pereant et imputantur*, Mart. v. 20. 11, is said to have been translated locally, 'They perish and are not thought of,' and to have been taken as referring to the Fellows of the College.

b. The gnomon of a small dial on a chimney near the kitchen appears to be represented in Loggan's engraving of 1675.

BRASENOSE COLLEGE. **1719.**

24. In the front Quadrangle, and now in good repair. The arms of the College are blazoned in the middle of the face. The original cost was under £9; the painting and gilding costing £7 7*s*.



BRASENOSE SUNDIAL, 1923.

CORPUS CHRISTI COLLEGE. Figured by Williams 1733.

Under the battlements of the Tower over the Great Gate.

CHRIST CHURCH. 1705.

25. Near the top of the southern square turret at the east end of the Cathedral. The gnomon is still standing, but the dial face has been weathered away.

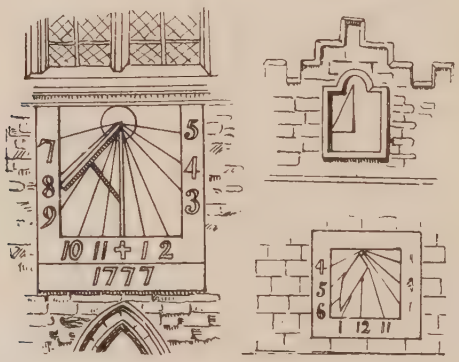
c. 1750.

26. A large dial on the end of the west wing of Peckwater Quadrangle marked for hours VII . . . IV. Repainted in 1916.

TRINITY COLLEGE.

Francis Potter, 1595-1678, a discoverer of the number of the beast and possessor of 'an excellent philosophicall head', 'made a fine diall with its furniture, on the north

ST. JOHN'S.



ST. PETER'S IN THE EAST. TRINITY.

wall of the (original) quadrangle at Trinity College, which he did by Samminitiatus's booke of Dialling (it haz been gone about 1670, and another is there putt).'

a. Figured by Loggan in 1675.

In the front Quadrangle.

b. 1733–1802.

In the north Court in the pediment, with which it was doubtless demolished in 1802.

c. A 'fine diall' over the College Library was attributed by Aubrey to Henry Gellibrand.

St. John's College. Indicated by Loggan in 1675, but shown more clearly by Williams in 1733.

Against the south side of the Chapel, where the battlements have been raised up in steps so as to make room for it.

27, 28. Wadham College. Indicated by Loggan 1675.

The gnomons of two south dials are still *in situ* on the south side of the south-eastern buttress of the Chapel, but the faces of the dials have perished. The lower and probably older one may be contemporaneous with the Chapel (1612): the other, possibly a more accurate time-indicator, may have been added in the scientific days of Warden Wilkins (1648–59).

Loggan is celebrated for the accuracy of his plates and for his remarkable powers of observation. In the case of one of these dials he has surpassed himself, for though the dial would not be visible from the point of view from which his drawing was made, yet he has indicated its position by showing the gnomon by the faintest possible scratch that might pass for a slip of the graver was it not more likely to escape observation altogether; as, indeed, it has been by the College historian and architect, Mr. T. G. Jackson, in his history of the College.

St. Mary Hall.

I have not succeeded in ascertaining the situation of this dial.

29. Holywell Church.

Still in existence on the Tower.

30. St. Peter's in the East.

Figured in Pugin, *Specimens of Gothic Architecture*, 1777; Ackermann, *Oxford*, 1814.

A dial about 3 feet square is in a shallow recess over the south door. Some of the lines on the face can still be traced, but the gnomon is missing and the dial is overshadowed by a luxuriant yew-tree.

The Church accounts for 1689 include a 'Mem. that Mr. John Prijon and Mr. Henry Wyldgoose nue drawed and painted the Dial gratis'.[1]

31. St. Thomas the Martyr. **Dated 1621.**

South Porch. Over a stone marked E F T B.

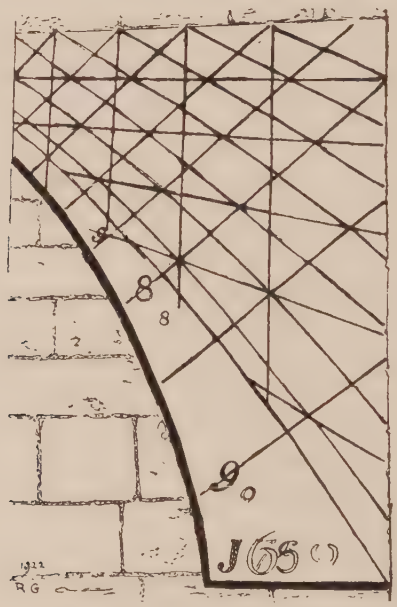
Dials facing East or South-East

32. Merton College.

a. **Dated 1659.**

On the east side of the last buttress against the north wall of the Chapel.

It was said to have been constructed by Jo. Bain-



Merton College Chapel.[2]

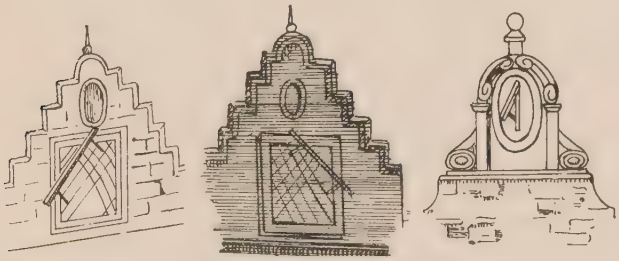
bridge who became a master-commoner of Merton in 1619, but as he died in the house opposite the college in 1643, the date on the dial may either refer to a repainting

[1] *Proc. Oxford Arch. and Hist. Soc.* i. 298.

[2] The cost of the photograph, from which this figure was drawn, was defrayed with a Treasury note seen floating down the Thames by the Librarian of Merton and rescued by the Librarian of Magdalen.

after his death, or be accepted as evidence that the dial was not by Bainbridge. On the other hand there is a drawing of the dial by Pugin in his *Specimens of Gothic Architecture*, with the shadow of the buttress reaching the 6 o'clock line, when Pugin is hardly likely to have been in College, and with a date, 1622, clearly engraved below the dial. This would agree with the Bainbridge tradition. The dial only functions between 6 a.m. and 9 a.m. in the summer months.

A small extension of the dial, apparently for use before 6 o'clock in the morning, is shown on the south side of the buttress in the engraving over the *Oxford*



MERTON EAST AND WEST. MAGDALEN.

Almanack for 1788, but the lines there shown are no longer visible on the wall-face.

It has no separate gnomon, since the adjoining buttress, throwing a shadow on the dial, serves that purpose. (Uffenbach, 3rd September 1710.) Mr. Allen informs me that the date appears to have been altered to '1729'.

b. **1610–1773.**

Figured by Loggan and, better, by Williams.

On the west side of the Fellows Quadrangle.

MAGDALEN COLLEGE. **c. 1635–1824.**

On the battlements over the east side of the Library: visible from the cloisters. The illustration in Ackermann's *Oxford* (1814) shows it to have had an oval face built in a rococco scroll-work frame that was afterwards considered to accord so little with perpendicular gothic that it was removed, probably about the time of the

rebuilding of the north side of the cloisters in 1824. It is represented in views of the cloisters by Wyatt, 1791, and J. Buckler, 1811.

New Inn Hall. Indicated by Loggan, **1675**.

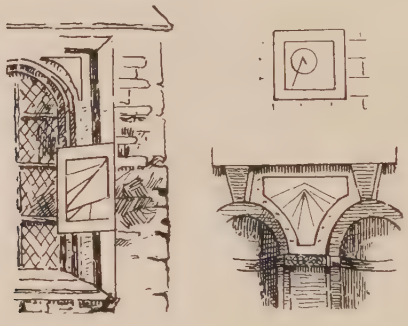
A small dial against the side of a window facing south-east.

Dials facing South-West

33, 34. Physic Garden. ? By Nicholas Stone, **1632**.

The two vertical dials, one on each side of the Danby Gateway, may have been part of the original design of

Brasenose.



New Inn Hall. Physic Garden.

Nic. Stone; or, like the statues of Kings Charles I and II, they may have been added at a later date, perhaps *c.* 1694–5, when carvers' bills were paid. Both have lost their gnomons, but their hour lines are still traceable. They could and should be restored.

Dials facing West

None of the following is now extant.

Merton College. Figured by Williams, **1733**. **1610–1773**.

In the Fellows Quadrangle facing the East dial.

Exeter College. Figured by Loggan, **1675**.

In the front Quadrangle facing the College Gate. Hours marked 2–6.

MAGDALEN COLLEGE. Figured by Loggan, 1675.

On the west wall of the Library: visible from the President's Lodgings and Garden. Hours marked 2 . . . 6.

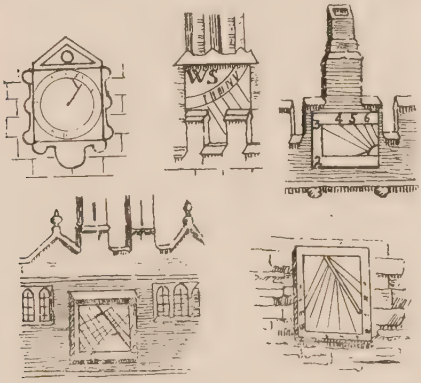
CHRIST CHURCH. Figured by Loggan, 1673.

a. A small dial on the buttress beneath the statue of St. Frideswide. All traces were removed at the time of the last refacing of the masonry.

1673.

b. Near the end of the south transept of the Cathedral

CHRIST CHURCH. ST. JOHN'S. MAGDALEN.



EXETER. TRINITY.

Dials facing West.

adjoining the Chapter House, and facing the Cloister, but not now traceable.

TRINITY COLLEGE. Figured by Williams, 1733.

Against the middle of the wall of the first court.

ST. JOHN'S COLLEGE. Figured by Loggan, 1675.

A small dial marked 'W.S' upon the west side of a chimney stack overlooking St. Giles. Hours marked I . . . IIII.

MISCELLANEOUS FIXED DIALS

Reflecting Dial. **1647.**

Not now extant. ? Wadham College.

By Christopher Wren.

It is recorded that Wren in 1647, when only 15 years of age, and a scholar of Wadham, translated Oughtred's *Geometrical Dialling* into Latin, and afterwards drew a reflecting dial on the ceiling of a room, embellished with an inscription and with various devices, including emblematical figures of Astronomy and Geometry and their attributes.[1]

CHR. WREN.
ANGUSTIS SATAGENS HIS LAQUEARIBUS
AD COELI METHODUM TEMPORA PINGERE
A PHOEBO OBTINUIT LUMINIS UT SUI
IDAEAM SPECULO LINQUERET AEMULAM
QUAE COELUM HOC PERAGRET LUCE VICARIA
CURSUSQUE EFFIGIEM FINGERET ANNUI
POST ANNOS EPOCHAE
VIRGINEO QVIBVS
VERE FACTVS HOMO EST EX VTERO DEVS
ETAT ISQVE SVAE NVPERAE.

The method was probably that described by John Lyon, 'Professor of this or any other part of the Mathematicks, neer Sommerset House in the Strand,' in an Appendix to J. Collins' book on the *Sector*, entitled *Reflected Dyalling from a glass placed at any Reclination*, 1658. For a complete exposition of the art see Maignan, *Perspectiva Horaria*, a finely illustrated book published in Rome in 1648, one year later than Wren's dial.

35. Window Dial. **17th cent.**

The only window dial in Oxford is in the west window of the Convocation House. It is a beautiful little example of the art of glass painting, showing the afternoon hours II to VIII in a yellow border, round paintings of a yellow brimstone butterfly, a rose, and some flying insect resembling a gnat.

There are two glass dials in the Evans collection; the smaller one dated 1648 has hour lines for 4 to XI, the other, 9½ inches square, undated, has hour lines for IIII

[1] Elmes, *Life and Works of Wren.*

THE YOULBURY SUNDIAL, PERHAPS THE FIR

Designed and erected by Sir A

ARK BOTH SUMMFR AND WINTER TIME

ns as a War Memorial

to IX radiating from a panel containing the crest of the owner, a Wing charged with 3 crescents on a pale. The mottoes are: *Vesper in Ambiguo est. Mora noxia cras nil age(n)dum.* On the dial is painted a goldfinch on a perch.

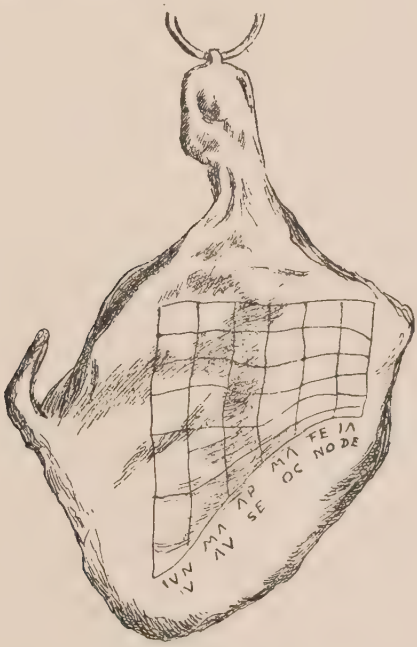
PORTABLE SUNDIALS

The shapes of portable sundials are legion. As timepieces their theory depends on one of two principles—either upon the altitude of the sun above the horizon or else on its position in its daily course. Both types were doubtless independently evolved from fixed dials.

A. *Sundials depending on the sun's altitude*[1]

With correction-scale for months.

Roman 'Ham' Dial. c. A.D. 65–79.

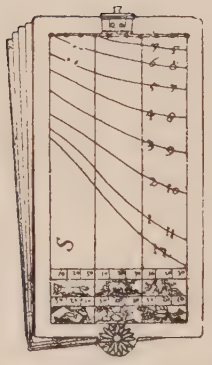


ROMAN 'HAM' DIAL.

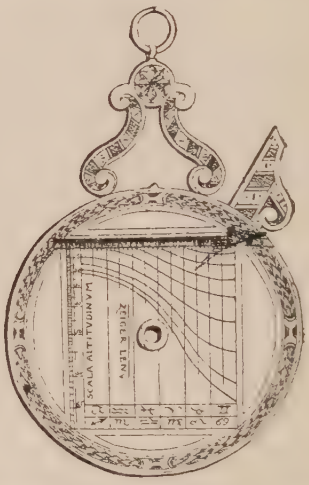
[1] Astronomers have credited Ahmed Ibn Abdallah, called Habash, with having made the first attempt to obtain time from observations of the sun's altitude in A.D. 829.

The earliest known specimen of a portable dial constructed upon this principle is a ham-shaped bronze dial excavated at Herculaneum.

Modifications of the same type of dial were in use in



German Tablets, *c.* 1680.
Evans collection, Scale $\frac{1}{2}$.

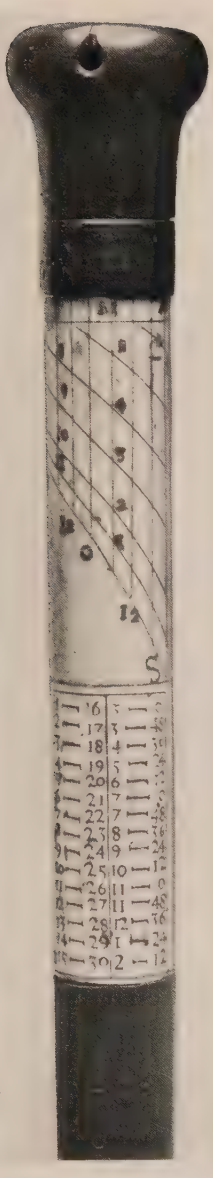


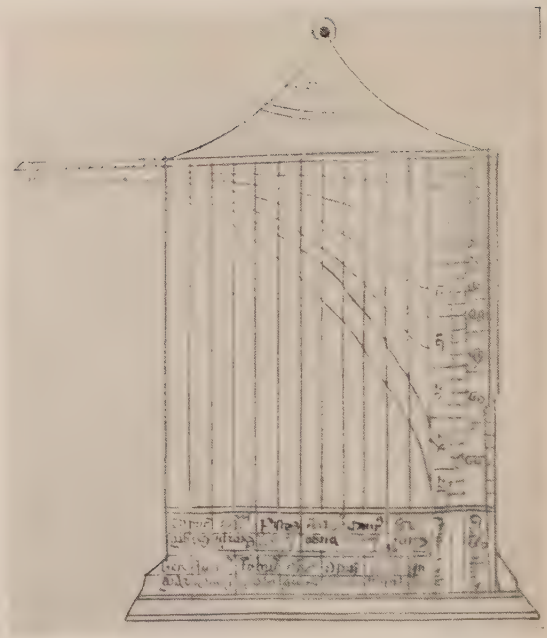
German Nocturnal Dial, *c.* 1650.
Evans collection, Scale $\frac{1}{2}$.

Europe in the seventeenth century. In two of Mr. Evans' examples, the gnomon could be moved along so as to stand over any desired month, whereas in the Herculaneum dial, the adjustment was made by bending the wire gnomon.[1]

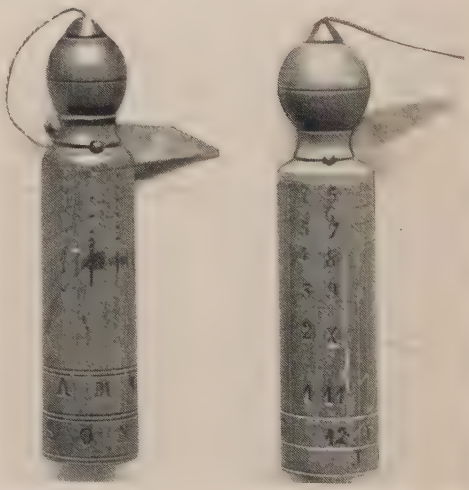
By drawing the correction-scale of months round a cylinder, the 'pillar', 'column', or 'Shepherds' dial' was devised.

[1] L. Evans, *Portable Sundials.*





MS. Ashmole 1522



NO. 37

NO. 38

DRAWING OF CHILINDRE C. 1350 AND PILLAR DIALS

Pillar Dials

The Chilindre or Pillar Dial has been derived from an ingeniously contrived dial of which the origin is to be sought among the Mediterranean peoples. One of the earliest treatises upon it by an Englishman is the *Practica chilindri*, written by John Hoveden, Chaplain to Queen Eleanor the mother of King Edward II.

The editor and translator of the treatise, Edmund Brock,[1] makes out that the particular chilindre described was made for latitude 51° 56′, which was probably intended for the latitude of Oxford. This surmise is supported by another Bodleian MS. entitled 'Composicio chilindri cum ejus operacione que facta est apud Oxoniam'—MS. Digby 98—from which we gather that there must have been competent dial makers in the City at that early date.

Early Drawings of the Chilindre.

a. In MS. Ashmole 1522, f. 181 b. **Before 1350.**

b. In MS. Hertford 3, f. 12 b.

c. Sebastian Münster's Engraving, in *Compositio horologiorum*, c. 39. **1531.**

36. Paper Scale for a Chilindre. **17th cent.**

Horologium solare cylindricum charta impressum.

No. 2989 in the 1697 catalogue of the Bodleian Library.

This cylindrical dial was catalogued with miscellaneous fragments including a Chinese piece, a fragment of a Japanese calendar, and a Persian letter, none of them at present identifiable (H. Craster). The dial may have been an engraved figure like the illustration in Kircher.

[1] Edmund Brock, *A Latin Treatise on the Chilindre, XIII Cent. Practica Chilindri* (Sloane MS. 1620, f. 2). Reprinted with a translation by Brock, for the Chaucer Society.

Brock's text is taken from Arundel MS. 292 collated with Egerton MS. 843 and Cotton MS. Vitellius A. i. Other copies exist: Camb. MS. Ii. i. 13, Bodl. MS. 41, Ashmole MS. 1522. Paragraphs on the marking of the chilindre in Camb. MS. Ii. i. 15 and Hh. vi. 8, Egerton MS. 843. Also in the Addit. MS. 24,010, written in 1551 or 1552, is a note on the *Compositio Cylindri* with a square diagram and a sketch of the complete instrument.

37. 'Column', 'pillar', or 'Shepherd's dial'.

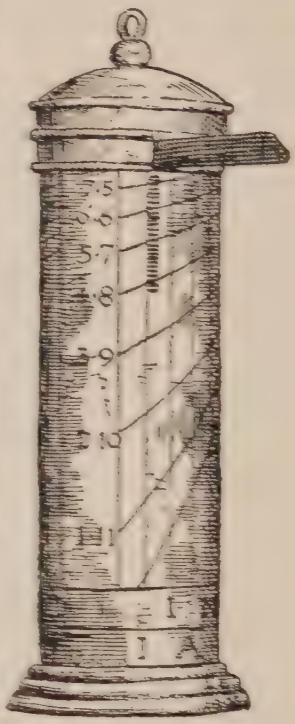
17th cent.

O. C. xxx Ashmolean Museum.

The dial forms part of the bone handle of *Absalom Leech's* Walking Stick and measuring rod.

A hinged gnomon (now missing) is brought over the proper month as indicated by the vertical lines. The stick, held upright, is then turned until the shadow of the gnomon falls vertically on the column. The position of the point of the shadow with reference to the oblique hour lines will then indicate the time.

Beneath the dial is a table for calculating the time of the southing of the moon on successive days of the month; and on the top of the handle a perpetual calendar, see p. 286.



PILLAR DIAL, 17TH CENT.
From a drawing by Mr. L. Evans.

38 *a–f.* **Pillar Dials.** (6.)

19th cent.

Pitt-Rivers Museum.

Used by the Basques.

Until recently such column dials were in common use in the Pyrenees.

RING DIALS

In the 'ham' and 'pillar' dials the portion of the scale that is used varies with the month of the year. In the ring dial the scale is fixed, but the position of the ray of sunlight by which the observation is made is moved to correspond with the month.

One of the oldest ring dials in this country is one in the British Museum, made about 1400; they were

in common use in the seventeenth and eighteenth centuries. Their essential features seem to have been foreshadowed by the ancient instruments, Ptolemy's Astrolabium and the Astronomical Ring.

Ptolemy's Astrolabium.

The astrolabium of Ptolemy consisted of a graduated circle inside which a second circle could slide, carrying two small cylinders diametrically opposite to each other. When an observation was made the instrument was kept vertical by a plumb-line. In use the movable double ring was set in the direction of the sun when on the meridian or towards a known star on the ecliptic—and then by directing the sights of the smallest ring to an unknown star—the readings would then give the latitude and longitude. (See p. 13.)

1. Meridian. } Polar Axis.
2. Outer movable ring. } Polar Axis.
3. Solstitial colure with longitude divisions on Ecliptic. } Ecliptic Axis.
4. Inner movable ring with altitude divisions. } Ecliptic Axis.
5. Sliding ring with sights and indices for altitude.

Abul Wefa described a meridian circle for observing the sun (Sédillot, *Mém.*, p. 196), while smaller circles became extensively used especially by navigators.

Astronomical Ring.

The astronomical ring consists of a metal ring which can be suspended by a bracket and ring. At a point half a right angle distant from the point of suspension a conical hole is made through the ring, with its apex towards the inside. Through this the sun's rays pass making a spot of light upon the half ring opposite the hole, which is divided into 90 parts. The sun's altitude can be at once read off from the top end of the scale or its zenith distance from the lower end.

There is no old specimen of the astronomical ring known to us among the Oxford instruments, but the principle of the instrument is involved in the construction of the Ring Dials.

Kratzer's Ring Dial. **c. 1520.**

KRATZER described the use of the ring in his *De Horologiis*, from which we reproduce the beginning of the chapter *De usu annuli* and his explanatory drawing. Kratzer's MS. is Corpus Christi College MS. No. 152.

39. Corean Sun Clock. **Modern.**

A wooden ring dial. Pitt-Rivers Museum.

Diameter $2\frac{1}{2}$ inches.

The Ring dial is so made that a small ring, with a pin-hole in it, revolves in a groove in the main ring, which is slotted in portions of its circumference so that, the revolving ring being adjusted for the day of the year, and the ring suspended, the sun may shine through the pin-hole on to the inside of the ring on which the hour lines are engraved. The instrument is provided with a set of 11 hour-cards marked on both sides, for use in different seasons.

40. English Ring Dial. **c. 1680.**

[5829. 1886] Ashmolean Museum.

Diameter $1\frac{1}{2}$ inch.

41. Ring Dial. **17th cent.**

Professor Bowman's Coll.

Diameter $1\frac{1}{2}$ inch.

Found on Greenham Common near Newbury.

I shew y^e time
if y^e Sun shine

RING DIAL.

42. English Ring Dial. **c. 1740.**

Diameter $2\frac{1}{8}$ inches. Ashmolean Museum.

The inner sliding ring is missing.

43-48. English Ring Dials (6).

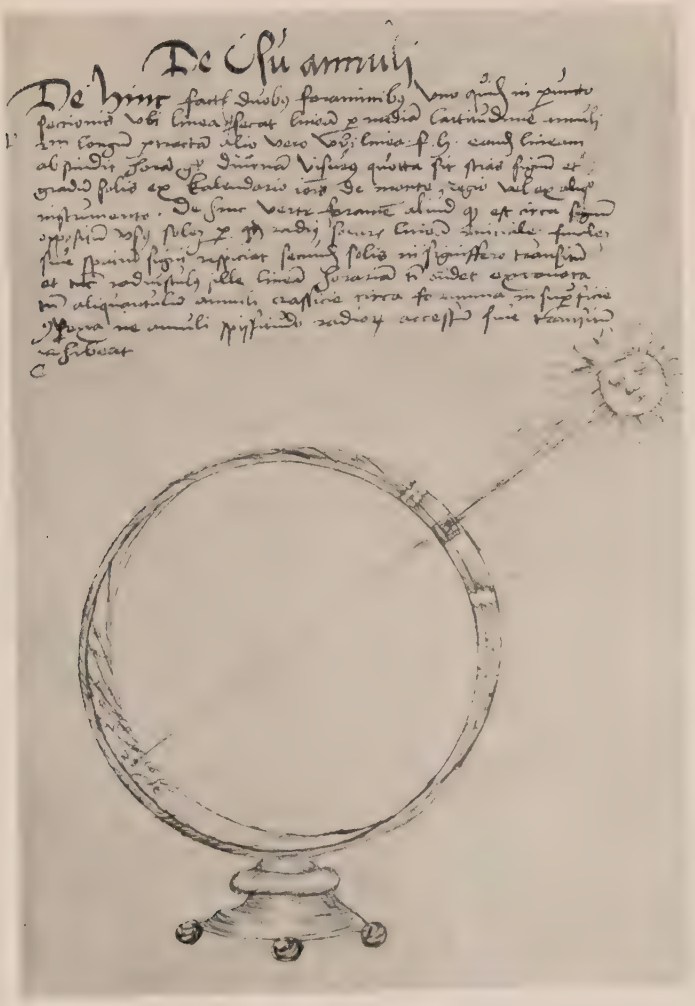
Pitt-Rivers Museum.

a. Diameter $1\frac{7}{16}$ inches, with an inner ring of copper.

b. Diameter 2 inches. Brass. Pitt-Rivers Museum.

c. Diameter $2\frac{3}{16}$ inches. Brass. ,,

According to an advertisement in W. O[ughtred], *Description of the Horological Ring*, 1674, 'This or any other Mathematical Instruments either in Silver, Brass



KRATZER'S STANDING RING DIAL, C. 1520

From his MS. 'De Horologiis', Corpus Christi Coll. MS. 152

or Wood are exactly made by Hilkiah Bedford, in Fleetstreet near Fetter Lane end.'

For **Universal Astronomical Ring Dials,** see p. 151.

B. *Compass Dials*

When the position of the sun in its daily path from east to west is used in these dial timepieces, two conditions are necessary. The gnomon must be inclined at an angle corresponding with the latitude of the place, and when an observation is made both gnomon and the 12 o'clock line must lie in the meridian.

The inclination of the gnomon may be fixed if the dial be intended for use in one latitude only, or adjustable if the dial is to be universal. The orientation in the meridian is effected by a magnetic compass—hence the name Compass dial.

Compass dials with string gnomon

One of the most ancient of these portable dials is preserved in the Museum at Innsbruck. It is dated 1451 and is supposed to have been made for the Emperor Frederick III. Another, engraved with the Hapsburg arms and dated 1453, is in the British Museum.

A description of the Innsbruck dial has been given by A. Wolkenhauer.[1] It is believed to have been made in Vienna, where Purbach wrote his *Compositio compassi cum regula ad omnia climata.*

The dial-plane measures 78 × 59 mm. and holds a compass. On lifting the shield-shaped lid, a string serving as gnomon is drawn up. (Ravenstein's *Behaim.*)

During the sixteenth century Nuremberg became the manufacturing centre for these string dials, which were usually made in the shape of a square box. *Cf.* P. Apianus, *Cosmographicus Liber*, 1528.

49. Pocket String Compass Dial, Almanack, and Tide-tables. 1554.

Bodleian Library.

Maker's initials, V. C.

A most elaborate instrument and book of tables in gilt

[1] *Mitt. geogr. Ges. München*, i, 1905, p. 251.

brass, with a ring for suspension. Both front and back are embellished with engraved ornament.[1]

Front. In a square frame an ovoid boss with a coat of arms [ ], three bars [ ], in chief [ ] as many roundels [ ]. Crest, a buck on an esquire's helmet. Above in a pediment, two cherub heads on a globe and two quadrants.

Back. Motto in oval

+ Aske + me +
+ not + for + ye +
+ Gett + me + not +
+ R + P +

Under a pediment above, an astrolabe. One of the two cherub heads is used as a catch.

Round the edge is an engraved border that resembles the work upon the book-dial (Brit. Mus. 88. 12–1. 294) and also appears on the work of V. S. (= Ulricus Schniep) in the Miller collection at the S. Kensington Museum and in several examples in the Evans collection.

This composite instrument is described in detail in the chapter devoted to Almanacks. See p. 279. Two of the leaves were fitted and engraved for use as a horizontal string-dial. The instrument was orientated by a small compass, and could be levelled with a clinometer.

50. Compass Dial in a Finger Ring. 1579.

No. 516, Fortnum Coll., Ashmolean Museum.

Inscribed with initials V. M. N. and on a shield a plant with 3 flowers.

German.

On raising the hinged cover of a small box, the gnomon string of this tiny dial is stretched, and on being orientated by the compass the hour can be read by a circle barely ½ inch in diameter.

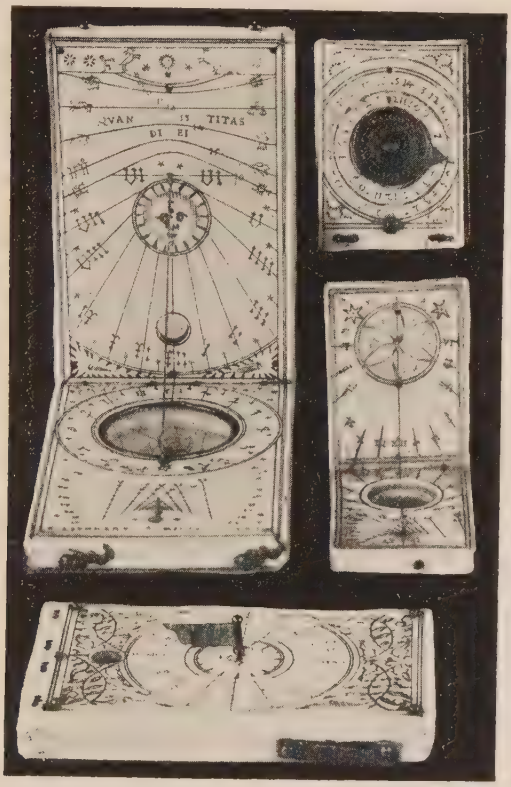
[1] The elegant style of engraved ornament upon the back and front of this instrument was much in vogue, both in western Germany and in Holland, during the second half of the sixteenth century—witness the decorative frames enclosing the titles of Eden's *Arte of Navigation*, 1561, or of the charts of I. Wagenaer collected in Auregain, *Speculum nauticum*, 1583, and again in the more finely executed plates by Theodore de Bry in A. Ashley's *The Mariners Mirror*, 1588.

NO. 49. V. C.'S POCKET DIAL, 1554

Bodleian Library

51. Tablet Compass Dial and Wind Vane. 1614.
Size $3\frac{1}{2}$ inches × $2\frac{1}{4}$ inches. Ashmolean Museum.
Presented by Greville J. Chester, 1865–7.

1614.



c. 1620.

Ivory Tablet Dials and Wind Vane.

By *Lienhart Miller*, 1614.[1]
Engraved ivory, coloured.
The instrument consists of two ivory leaves hinged together.

[1] Lienhart or Leonhart Miller's date is given as 1602–44, but Mr. Lewis Evans has noted his mark as late as 1674.

(1) The upper surface is engraved with a compass dial, marked

NORT. NORT.OOST OOST.OOST SVD, &c.

in the centre of which a small wind vane can be mounted. When not in use the wind vane is carried in a covered slot at the side of the lower leaf.

Inside the lower leaf is (2) an ordinary horizontal hour circle surrounding (3) a compass with the 4 cardinal points, SEPT ORIE MERI OCCI; on the inside of the upper leaf is (4) a vertical dial for use with the same string gnomon, indicating 'planetary' and 'equal hours' for c. latitude 49°, also (5) a dial with a perpendicular style (missing) for indicating the QUANTITAS DIEI (= length of the day), the Italian and Babylonish hours. On the lower leaf too is (6) a subsidiary horizontal dial for Italian hours.

On the under surface is a volvelle, or rundle of gilt brass, border numbered 1–12, 1–12, with an index working on circles to indicate the moon's age, time of rising, &c.

52. Tablet Dial and Compass. c. 1620.

Size $1\frac{7}{8}$ inches × $1\frac{1}{4}$ inches. Ashmolean Museum.

Engraved ivory.

A much smaller instrument of the same kind with three dials only, viz. horizontal and vertical dials with the same string gnomon, and a horizontal dial to show the Italian hours.

A small rundle on the back.

53–55. Chinese Sundial and Compass. 1796.

a. Presented by W. Lloyd. No. 66, Old Ashm. Cat.
b. and *c.* Pitt-Rivers Museum.

Ivory Portaria made at Nuremberg in the sixteenth and seventeenth centuries resemble the small portable tablet dials of the Chinese so closely, that the conclusion is inevitable that the latter were copied from the former.

Compass dials with pin gnomons

Sundial and Compass. 1730–40.

Brass, octagonal. Diameter 2 inches.

In the possession of J. H. Hume-Rothery, Esq.

Inscr.: 'And. Vogl'.

The following latitudes are inscribed underneath the compass box:

Elev Pol, Augsburg Pari 48, *Cracau Pra* 50, *Leipzig* 51.

55*. Sundial and Compass. 1740–50.

No. 1913. 916, Ashmolean Museum.

Brass, octagonal. Diameter 2 inches.

'Johan Schretteger in Augsburg.'

The hour ring and pin gnomon are adjustable. There is a quadrant for setting the hour ring for the latitude. This and the gnomon fold flat over the face of the compass.

Sundial and Compass. 18th cent.

Gilt Brass, octagonal. Diameter 3 inches. Gunther coll.

With adjustable hour ring like the last but with small, folding plummet in addition.

The following latitudes are inscribed underneath the compass box:

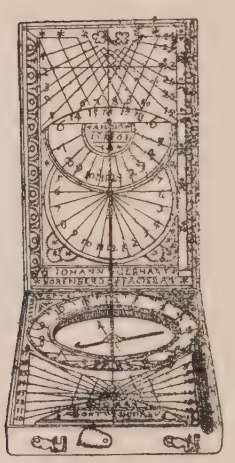
Elev. Poli. Lisbon 39, *Rom* 42, *Venedig* 45, *Wien. Augsp.* 48, *Nürnb* 49, *Prag* 50, *Warschau* 52, *Lübeck* 53, *Hambu* 54, *Riga* 56, *Moscau* 57, *Petersbu, Stockholm* 60.

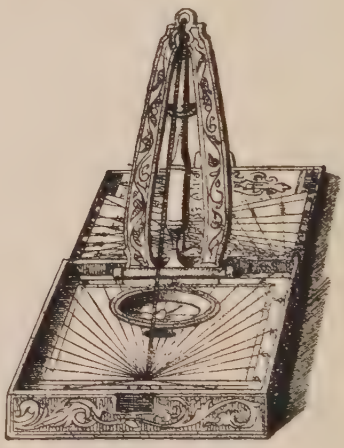
The total number of early pocket dials still remaining in Oxford is very small. But at the present time we are fortunate in having a loan exhibition of the finest private collection of such objects in Britain. It was formed by Mr. Lewis Evans, F.S.A., and is on offer to the University on the reasonable condition that a suitable place for its permanent exhibition shall be found. The value of the collection has been seriously misrepresented in a letter to the press[1] as being of the eighteenth and nineteenth centuries. Its strength lies in the many beautiful examples of the work of earlier makers.[2] The earliest is dated 1481. English makers are represented by Humfrey Cole 1568, Whitwell 1593, Elias Allen *c.* 1620, Edmund Culpeper 1666, Sam. Rolfe 17th cent., Iohn Coggs 1690–1700, John Rowley *c.* 1710, Wm. Deane 1720, J. Sisson 1735, John Fowler 1737, John

[1] *The Times*, 2 December, 1922.

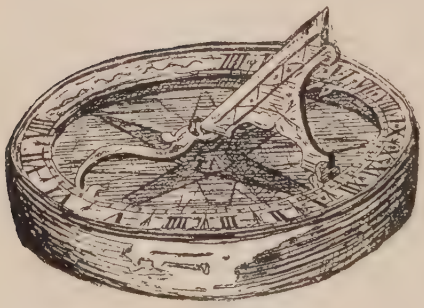
[2] Notes on several of these makers are printed in vol. i, pp. 173–183.

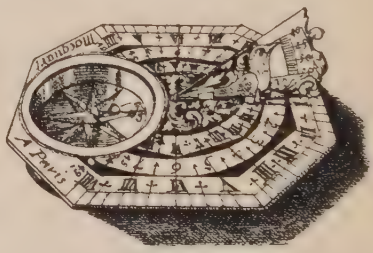
JAPANESE SILVER DIAL (Scale ½).





Ivory, by Gebhardt, 1561. *Gilt brass, by Ulric Schniep, c.* 1590.
GERMAN STRING COMPASS DIALS.





Brass Box Dial, 17th cent. *French Dial, by Macquart, c.* 1740.
COMPASS POCKET DIALS FROM THE LEWIS EVANS COLLECTION.

Nemes *c.* 1740, Th. Wright 1740, Heath and Wing 1768, Bennett of Cork *c.* 1780–1800, C. Harrison 1810, and there is also an Elizabethan Finger Ring-dial in silver.

The French series illustrates the work of Bion *c.* 1710, Butterfield *c.* 1680, Le Maire *c.* 1750, P. Danfries 1585, Seb. Thibault 1588, Macquart 1742, Ch. Bloud *c.* 1670, Lasnier 1740.

Among the German makers figure Christopher Schissler (p. 232), Ulric Schniep 1553–88, Marcus Purman 1594, Johan Gebhart 1557–61, Hans Ducher 1567–88, H. Reinmann 1558, Paul Reinmann 1578–1607, Leinhart Miller 1613–32, Hans Troschel 1640, Johan Martin *alias* Willebrand, *c.* 1705, and other eminent makers.

A few figures of some typical pocket dials were drawn by Mr. Evans to illustrate his article on *Portable Sundials* published as a last chapter to the 1900 edition of Gatty's *Book of Sundials*. By the courtesy of Messrs. George Bell and Sons and of Mr. Evans, we are able to publish a selection of these illustrations of a few of the hundreds of dials now offered to the University and on view in the Bodleian Library in Oxford.

LIST OF PROMINENT EUROPEAN MAKERS OF PORTABLE SUNDIALS

Germany

LINHART GRESEL Ivory dial at S.K.	Nuremberg 1531.
CASPAR VOPEL b. 1511 in Westphalia	1541–51.
JOHANN GEBHART Maker of Ivory dials	1546–60.
CHRISTIAN HEIDEN, 1526–76	Nuremberg? 1553–69.
CHRISTOPHER SCHISSLER	Augsburg 1552–82.
ULRICUS SCHNIEP	Munich 1553–88.
ALEXIUS ,,	,, 1578.
GEORGIUS REINMAN	Nuremberg 1555.
HIERONIMUS REINMAN d. 1577	,, 1558–63.
PAULUS REINMAN	,, 1578–1607.
HANS FELD	1566.
HANS TUCHER	Nuremberg 1567–1612.
HANS TROSCHEL	,, 1580–1627.
ULRICH KLIBER	Augsburg 1555–61.[1]
THOBIAS ,,	(B.M.) ,, 1595.
CHR. KELLER	Linz 1590.
MARTIN FREY	Regensburg 1590.
G. KARL	1598.
TOBIAS VOLCKMER[2]	Brunswick 1584–1626.

[1] Mr. Claude Fry has a dial marked 'VDalrion⁹ Klieber fciebhat anna 1561'.

[2] C. Fry collection.

Nicolaus Rugendas		Augsburg *c.* 1600.
Josua Habermel		Regensburg *c.* 1600.
Lienhart Miller		Innsbruck 1613–38.
Nicolaus „		„ 1642–51.
Conrad Karner		1632.
Albrecht „		1668.
J. M. Volckmair		L.E. 1647.
F. H. Müller		Cassel 1672–8.
Köhler		S.K. 1677.
Melchior Karner		1690.
M. I. Hager		Arnstadt *c.* 1690.
I. M. „		„ 1690–1700.
F. A. Knitl	S.K.	Linz 17th–18th cent.
Johan Martin		Augsburg 1703–6.
„ „ Willebrand		„ 1748.
L. Theodatus Müller		*c.* 1710.
J. G. Plöninger	L.E.	Munich 1720.
Leonhard Karner		1732.
A. Vogler		1730–40.
J. G. „		*c.* 1750.
A. Odelem		Brunswick 18th cent.
Joh. Engelbrecht		Bramau, Bohemia, 1776–1805.

Holland

Von Call	Nieumegen 1647.
W. Sneewins, prob. s. of Heindrick Sneewins	Delft 1703–9.
D. Trap	*c.* 1750.
Ian Areiaensen (C. F.)	
Barent Hendricks (C. F.) Amsterdam	

France

Sebastian Thibault		Dreux 1588.
Gribelin		Blois 1610.
B. B.		1655.
Dauid Asseline (Capt. Creagh-Osborne)		Dieppe —
Carolus Bloud Deppensis		Dieppe *c.* 1660–80.
Chapotot		Paris 1670–86.
Butterfield		„ 1679–90.
Charlemagne Viet (C. Fry)		Blois ? 1680–1720.
Piochat, Elève du Butterfield		Paris —
Nic. Bion		„ 1709.
Macquart		„ 1726–42.
„ and Cadot		„ 1730.
Cadot (son-in-law of Macquart)		„ 1742.
C. Langlois	aux Galleries	„ 1730–43.
Lasnier	aux deux Globes	„ 1740.
[Jacques] Le Maire	à la Pierre d'Aiman	„ 1745.
Baradelle		„ *c.* 1750.
George		„ *c.* 1750.
Michel Bourbon		1753.
Collet		Paris *c.* 1760.
Chesnon		Blois 18th cent.
Meurand	Quay de l'Horloge du Palais à Paris	1780.
Desnos (C. Fry)	rue S. Jacques à Paris	—

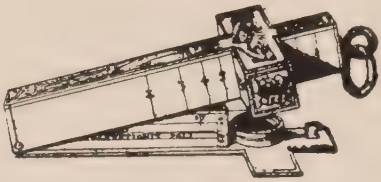
Italy

CAMILLO DELLA VOLPARIAE	Florence 1542–54.
GIROLAMO „ „	„ 1568, 1590.
AMELLI	Palermo *c.* 1580–1600.
ANDREA MAR (L.E.)	1589.
JACOBUS LUSUERG MUTINENSIS	Roma 1668–1719.
COSMUS THOMAS HUGGEFORDUS	Florence 1714.
NICHOLAUS BLONDEAU	Naples 1706.
CAVALIERO JOS. MARIA BARONE Sta CAETANI	Naples 1770.
LUIGI CERVELLATI	18th cent.
G. L. FRISI	1794.

Spain

F. PETRUS AGGERIUS	Madriti 1562.
F. H. DE ARRESSE	1598.

Italian Disk Dial, 1585.



German Crucifix Dial, 1596.
By Marcus Purman.

PORTABLE DIALS FROM THE LEWIS EVANS COLLECTION.

56. Pendent Sundial with a Calendar, Quadrants, and Volvelles for Solar and Lunar Calculations.[1] 1537.

Diameter $8\frac{7}{8}$ inches. St. John's College.

Inscribed: + *RODES* * *BRECHTE* 1537.

Engraved with two shields, one bearing a three-flowered thistle, the other a merchant's mark. Grafiti:—'T N' and the name 'Pointer' faintly scratched.

It therefore belonged to the persons who owned the Quadrant No. 69 described on p. 173.

[1] This dial was called an 'astrolabe' in the *Catalogue of the Loan Exhibition* of 1919.

Bequeathed *c.* 1754 by John Pointer to St. John's College.

Suspension: the ring is passed through a loop of metal riveted to the bracket: there is no swivel.

The Rule or alidade carries two sights in line with the 'line of trust' as well as a sliding pointer which can be set at different distances from the centre by a scale 10–60 corresponding to two radial scales flanking the scale of months on the face of the instrument.

The *Face* is covered with a number of scales and lines for the performance of a variety of operations.

Round all is a circle of 360 degrees. They are numbered by tens in the lower right-hand quadrant only, which is the one that would be used for measuring altitudes: in the other quadrants they are numbered by fifteens as hours 1–6 and 4–12, starting from the point of suspension (1, 2, and 3 being omitted in the left-hand semicircle).

The middle third of the upper part of the face is engraved as a Universal quadrangular Sundial, like the instrument figured under the name of 'Horarium generale' by Johannes Stöffler at the end of his *Calendarium Romanum* in 1518, and repeated with modifications in many works including those of Orontio Fineo.[1]

In connexion with this dial there is a scale of months (the 'signa Zodiaci' in Stöffler's instrument) immediately under the point of suspension, and a Zodiac scale ('signa meridiei', Stöffler) on the left margin, and a similar scale, left blank, on the right. The hours are numbered on the circumference of a circle: the numbers above the diameter indicate hours before noon and those below indicate hours after noon. The lower left-hand quadrant includes a projection of the zodiac as in the New Quadrant of Profacius, and in the corner a small scale of umbra recta and umbra versa.

The lower right-hand quadrant includes the 'instrumentum horarum' showing the unequal hours, while near the left side are lines for the equal hours, numbered 4 to 11. Traversing this quadrant too is the line inscribed 'via solis lunīē eclipt'.

On the *Back* are the solar and lunar volvelles. Enumerating the plates in order of superposition, we have—

1. Moon marker. A small gilt index and disk engraved with a moonface, which can be turned to point to any number in a circle divided into 19 parts on plate 3.
2. Sun marker. A small gilt index and disk engraved with

[1] Fineo, *De gli oriuoli*, p. 68, *Opere*, 1587.

Face

NO. 56. BRECHTE

St. J

Back

IT SUNDIAL, 1537

ge

a sunface, which can be turned to point to any dominical letter in a circle on plate 3.

3. Moon index disk 3 in. in diameter with an index $2\frac{3}{4}$ in. long reaching to the edge of the base plate. This disk is engraved with the owner's name and date, and his two shields, and carries the moon and sun markers. Through a large round aperture a portion of plate 4 is seen, showing the phases of the moon. Drawings of the Moon and the Scorpion are incised on the index, which moves over a circle on the rim of disk 4, which is divided into 30 parts, each subdivided into quarters.

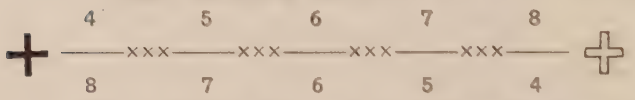
4. Sun index disk $3\frac{1}{2}$ in. in diameter with an index $2\frac{3}{5}$ in. long and three small indices quadrantly arranged. Representations of the Sun, the Lion, and two stars adorn the large index and show its purpose: it can be set by the outer circles of the base plate. The small indices point out the 12 Houses of Heaven which are numbered in both directions by the figures in the inner circles 12 and 13 upon the base plate.

5. The base plate. The wide border of the basal plate is filled with 13 concentric circles. Proceeding from without inwards, they are—

   1. Circle of 365 days. Division errors are especially noticeable in the case of the last days of months with 31 days.
   2. Dominical letters opposite particular days.
   3.) These three circles contain numerical tables for
   4.} astronomical calculations. There are 19 or 20
   5.) rows of figures to each month.
   6. Names of the Months. The 18th and last day of every month are also marked, except in the case of Mayus in which the 12th, 24th, and 31st are numbered.
   7. Names of Festivals of the Church. See below.
   8. Circle of degrees of the Zodiac.
   9. Numbers of degrees of the Zodiac.
   10. Names of the signs of the Zodiac.
   11. Illustrations of the signs of the Zodiac, with corresponding names of the Houses of Heaven.

Aries	Dom^{9} Martis	Libra	Dom^{9} vener^{s}
Taurus	Dom^{9} veners	Scorpio	Dom^{9} marts
Gemini	Dom^{9} m^{r}curÿ	Sagittarii'	Dom^{9} jovis
Cancer	Dom^{9} lune	Capricorn'	Dom^{9} saturni
Leo	Dom^{9} Solis	Aquar'	Dom^{9} Saturni
Virgo	Dom^{9} mcurij	Pisces	Dom^{9} Jovis

12.) 13.) A circle partly divided by stars into 48 parts, numbered in 12 groups of four between a black and a bright cross along two semicircles in both directions, thus:



These circles are used in setting the sun index disk 4.

The first point of Aries corresponds to 14 March on the outer circle.

List of 67 Festivals

Martius	1 david	David
	Iuliaē	? (Juliana's day is on 16 Feb.)
	15 Longi	Longinus of Jerusalem
	25 urladi	*Annunciatio Dominica
Aprilis	1 theod'	Theodora
	6 sixtus	Trans. Sixti I
	14 tyburc'	*Tiburtius
	25 Marc'	*Marcus Evang.
Mayus	1 Iacop	[Philippus et] Jacobus
	3 Crucis	*Inventio Crucis
	6 jō evā	*Johannes ante Portam Latinum
	14 bonifac	Bonifacius
	22 Helena	Helena
	30 Felicis	Felix (Pope Felix I)
Junius	1 nicome	Nicomedes
	12 basili	Basilides
	14 blasyl	Basilius
	24 Johān	*Nativitas S. Johannis Bapt.
	29 petri	*Petrus et Paulus
Julius	2 urladi	Visitatio B.V. Mariae
	Grība	Grimbaldus
	13 priua	Privatus (*cf.* a kalendar printed in England in 1568)
	15 swith	*Trans. S. Swithuni
	22 marie	*Maria Magdalena
	26 anna	Anna
Augustus	1 peter	*Festum S. Petri ad Vincula
	6 crist	? Cristus = Sixtus[1]
	10 laurē	*Laurentius

[1] Mr. Wilson suggests that this is most likely due to a misreading of Xistus (= Sixtus) as Cristus.

	13	ypoli	Hippolytus[1]
	15	urladi	*Assumptio B.V. Mariae
	24	Barto	*Bartholomaeus
	29	Johān'	Decollatio Johannis Baptistae
Septembris	1	gielis	Egidius (= Giles)
	8	urladi	*Nativitas B.V. Mariae
	14	Crucis	*Exaltatio Sanctae Crucis
	21	mathe	*Matthaeus
	29	michie	*Michaelis
Octobris	1	remig'	Remigius
	4	frācis	Franciscus
	10	victor	Victor
	14	calixt'	Calixtus
	18	lucas	*Lucas
	23	theodor	Theodoretus ('Theodour' in the Martyrology of Sion)
	28	simon	*Simon et Judas
Novembris	1	omnsct'	*Omnium Sanctorum
	6	leonar	Leonardus
	11	martī	*Martinus
	13	bricii	Britius
	19	Elizabt	Elizabetha
	25	kathe	*Katherina
	30	andre	*Andreas
Decembris	1	loy	Eligius (= Eloi)
	6	nicla	*Nicolaus
	8	wrladi	*Conceptio B.V. Mariae
	13	lucie	Lucia
	21	thome	*Thomas Ap.
	25	nativi	*Nativitas Domini
	29	thome	Thomas Archiepiscopus
Januari[9]	1	Circū	*Circumcisio Domini
	6	Ephi dī	*Epiphania Domini
	14	felicis	Felix (of Nola)
	17	Anthōi	Antonius
	25	pauli	*Conversio S. Pauli
Februari'	2	purifi	*Purificatio B.V.M.
	13	uulfrā	Vlfranus
	22	petri	*Cathedra S. Petri in Antiochia
	24	mathie	*Matthias

This instrument bears a longer list of Festivals than we have seen on any astrolabe. The Festivals of

[1] Inventor of the erroneous 16 years' cycle for finding time of Easter. The error was pointed out *c.* A.D. 240.

the Virgin Mary are uniformly inscribed as 'urladi', probably for 'wrladi' or our Lady Day, a designation which must be of English origin: either the instrument was made for English use, or derived its list of saints' days from an English source. The appearance of Grimbald and Swithun points the same way. Peter might be German as well as English. The 'ur' for 'our' points to a foreign workman, probably to one who was acquainted with the German equivalent, *Unser L. Frau* for La Madonna.

Of the 67 Festivals, the 33 marked with asterisks also occur in the list of 48 inscribed on an astrolabe of English make described by Ferguson.[1] The latter list includes Valentine, Cedda, Ambrose, George, and Dunstan, whose places are taken by Ulfran, David, Theodora, Sixtus, and Helena in our list; also the Lady Days, mostly inscribed Mari. Giles and Remigius are shared with another astrolabe list on an instrument in the Sloane collection in the British Museum. The other Festivals have not hitherto been described in this connexion.

A small 'thulthi' astrolabe, engraved for the latitude of Oxford and bequeathed by Dr. Caius to his Cambridge College, has 24 Saints' Days, evenly distributed over the months. This list[2] includes seven not found in our St. John's instrument. They are

March 12	Gregorius
April 4	Ambrosius
May 26	Augustinus Anglorum
June 11	Barnabas
July 7	Translatio S. Thomae
July 20	Margaretha
Nov. 23	Clemens

This astrolabe has been ascribed to the early fourteenth century.

Double Horizontal Dial

57. Oughtred's Double Horizontal Dial. 1632.

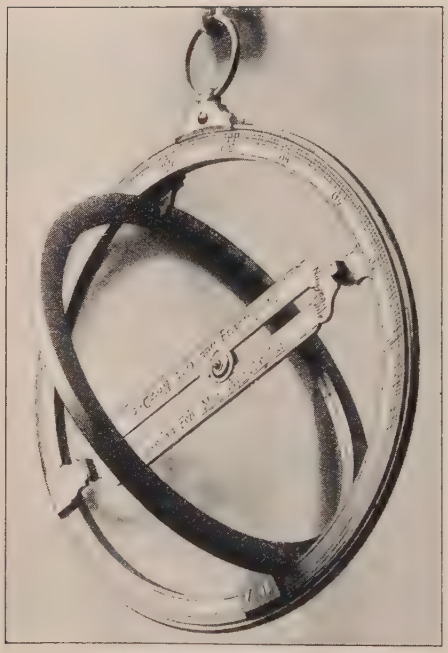
St. John's College.

By E. Allen.

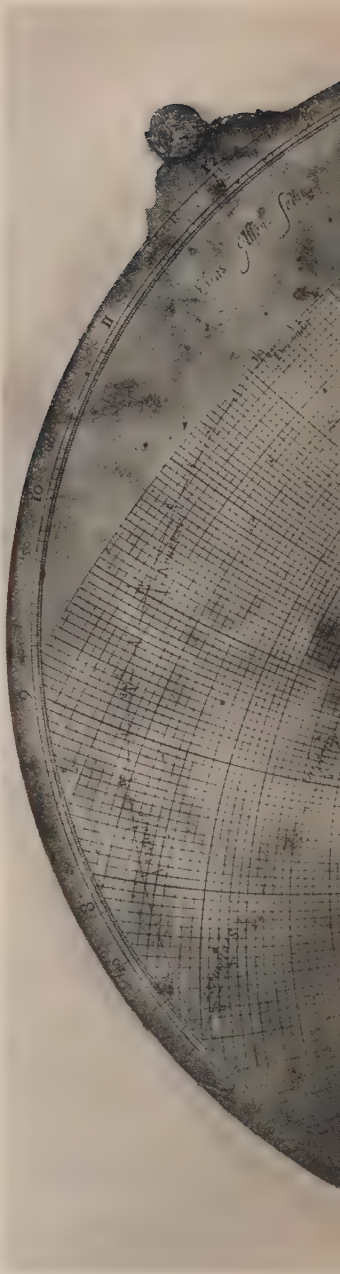
The 'Horizontall Instrument' is engraved on the face of the plate bearing the Circles of Proportion already

[1] *Archaeologia*, lii, p. 75.

[2] For a description of this instrument I am indebted to my friend Sir Hugh Anderson, the Master of Caius College.



OUGHTRED'S HOROLOGICAL RING



OUGHTRED'S DOUBLE HORIZONTAL DIAL, 1632

St. John's College

described in the account of the Mathematical Instruments. See vol. i, p. 151.

The Horizontall Instrument is a projection of the upper hemisphere upon the plane of the Horizon marked with the numbers of the hours and is traversed by a curve of months and days.

A median line passing through the 12 hour mark is marked at certain intervals PI, PW, and PII, which stand for Pole of the 1st semicircle of the Ecliptic, Pole of the World, and Pole of the 2nd semicircle of the Ecliptic, and are used to find the longitude of the sun, or the degree of the sign he is in, on any given day.

There are two thumb-screws and other attachments for an index or gnomon, but this and any other accessory parts have been lost long since. But see p. 388.

The twenty-four uses of the instrument are described in a work by W. O[ughtred], *The Description and use of the Double Horizontall Dyall. Whereby not onely the Houre of the Day is shewn; but also the Meridian Line is found: and most Astronomicall Questions, which may be done by the Globe are resolved.* Printed for Elias Allen 'maker of these and all other Mathematical Instruments and are to be sold at his Shop over against St Clements Church without Temple-barr.' 1632. The writer of the preface states that Oughtred had devised these instruments thirty years previously.

Oughtred's instrument, now in the Library of St. John's College, was presented to the College by George Barkham in 1638, together with a copy of the 1632 edition of the book, which has been amplified by additions and corrections in manuscript that were either taken from, or intended for, the second and illustrated edition that appeared in 1633. And yet a third edition of *The Circles of Proportion and the Horizontal Instrument* was edited by A. H[aughton] and was printed in Oxford in 1660.

An acrimonious controversy as to the invention of the instrument took place between Oughtred and the contemporary mathematician Delamain.

Oughtred's account of the affair is that Delamain

'having beene sworne his Majesties servant, had a purpose to present his Majesty with some New-yeares gift: and requested me to devise some pretty Instrument for him. I answered, that I have heard his Majesty delighted much in the great

concave Dyall at White-hall: and what fitter Instrument could he have then my Horizontall, which was the very same represented in flat? and that I would upon the backeside set the theorics of the Sun and Moone. And so by helpe of both sides Eclipses might be calculated with great facility. He liked it well. The Horizontall side was begunne by my direction. I was not long at home, but Master *Allen* being at a stand in his worke, sent to me for helpe. I writ him a large letter two sheets of paper long: wherein I taught him the uses of the Instrument especially the Horizontall: and afterward the fabric or delineation of it: and how to find the semidiameters and centres of the severall circles both great and lesser, and the way to divide them. Which letter Master *Allen* yet keepeth: and is the same I spake of before: and which *Delamain* confesseth he *saw*.' W. Oughtred, *An Apologeticall Epistle: The just Apologie of Wil: Oughired against the slaunderous insimulations of Richard Delamain.*[1]

Oughtred moreover affirmed that as long ago as 1603 he had presented a portable dial drawn with his own hand 'to the truely reverend Prelate Doctor Bylson, Bishop of Winchester, by whom I was made *presbyter*'. And again about the year 1608 he had 'bestowed one upon a noble Ladie, wife of a learned and worthy Knight, but since dwelling in Worcestershire'.

Dial Construction

Several Oxford authors have left books dealing with the construction of dials. An early treatise is that of Robert Fludd (1574–1637) of St. John's and Christ Church, 1605. It is entitled *De arte Scioterica* and is included in his *Macrocosmi Tractatus*, 1617. In the first chapter he describes the 'Regula Scioterica', which is little else than the rectangular protractor of modern times. The work of Gunter at Whitehall has been mentioned in vol. i, p. 115. His methods have been described by Foster, *The art of dialling; by a new easie and most speedy way*, 1638. From the Whitehall dials may have been copied the following.

58. Engravings for Portable Dial. 1669.

On paper. Burnet, i. 296, Hope Collection.

Engraved portraits of Charles and Catharine with

[1] Printed at the end of *Circles of Proportion*, 1633.

a pair of hexagonal dial-papers printed with hour lines marked 6–11 [a.m.] and 1 to 7 [p.m.] evidently taken from Gunter's great composite dial at Whitehall, and perhaps intended to be fixed to a pocket sundial.

Inscriptions with chronograms:

Regnet DIV CaroLVs	FaXIt RegIna Det RegI
IMperetqVe BrItannIs	RegnoqVe proLe M CatharIna
[MDCLVVVIIII = 1669]	[MDCLXVIIII = 1669]

A later work of local interest was T. E.'s [Thomas Edwards] *Dialling made easy; or, Tables Calculated for the Latitude of Oxford. By the help of which, and a Line of Chords, the Hour-Lines may quickly and exactly be Described, With some brief directions for making two sorts of Sun-dials.* Oxford, 1692.

For practical purposes dials could be accurately drawn by the use of the Dialling Sphere, of which there is a fine example at Christ Church.

Instrument for Drawing Dials

59. Dialling Sphere. c. 1700.

Diameter $10\frac{3}{8}$ inches; height 14 inches. Orrery Coll. 3.

Insc. I. Rowley fec.

With a contemporary manuscript describing its use, which may have been written by John Rowley himself. At any rate it is well worth printing in full.

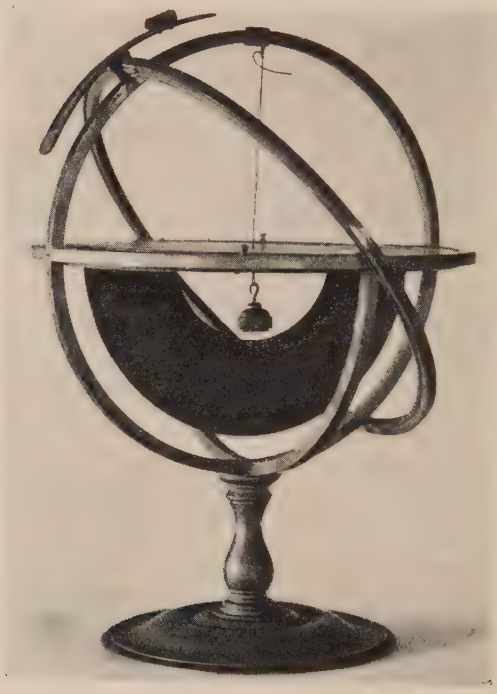
The Description and Use of the Dialing Sphere

This sphere consists cheifly of three of the great Circles of the Sphere, viz. the Meridian, Equinoctial & Horizon; besides a moveable Circle y^{t} moves in ye Plane of ye Horizontal Circle, by which all Declinations of Dial-Planes are represented. There is likewise a thin circular Plate of brass, moving upon two centres, to wch is fixt a thin semicircle of brass graduated into 190 Degrees beginning from ye upper edge of ye thin circular plate. Upon this semicircular plate is represented ye Inclination & Declination of all Dial Planes; the round thin Plate represents ye Plane itself.

To draw an Horizontal Dial for this Latt^{d}.

Set the equinoctial wch is figured 1, 2, 3, & on each side

meridian, the Circle being ½ cut in y^t part that moves on the Meridian to the Complement of y^e Latitude, & y^e Nutt, to wch the string is fixt, to the Lat^d of y^e Place; then the string represents y^e Axis of y^e World, & is at right to y^e Equinoctial; then moving the Wax Candle to every Hour on the Equi-



ROWLEY'S DIALLING SPHERE, *c.* 1700.
Orrery Collection.

noctial, the shadow of y^e string will shew every Hour's proper Distance on ye Plane.

To draw a Declining Dial.

Move that Circular Ring that is in ye Plane of the Horizon to the Declination, suppose 20 Degrees, by the two little buttons y^t are fastened to it, either East or West from ye Meridian; then will ye Candle mark out every Hour on the Plane as it is moved on the Equinoctial.

To draw a Declining Inclining Dial.
20 declining & 30 inclining Degrees.

Raise the round thin plate by the Semicircle underneath it to 30 Degrees from ye Axis or string, then move the Light to the several Hours on ye Equinoctial, which will shew all the unequal Hours on ye Declining Inclining Plane.

To draw a Declining Reclining Dial.
20 degrees Declining & 30 Reclining.

Depress the round thin Plate from ye Equinoctial 30 degrees, then will one part of ye Plane rise near the Axis of the World, then moving ye Light as before directed, the Hour Lines will be exprest on ye Plane.

There is a Quadrant of Altitude which being applied to the Horizon gives the stiles height, & substiles distance from ye Meridian.

The Sliding Peice that moves round the equinoctial has ye Declination on w^ch^; by raising or falling the candle to the Declination, is shewn the number of Hours the Sun shines on any Plane.

An apparatus with the essential parts of this Dialling Sphere was described in 1648 by Maignan, *Perspectiva Horaria*, and both instruments would have been evolved from a Sphere of the type of the one described by the Spaniard Marten Cortes in 1545, f. 87, cap. xi.

ARMILLAE

Armillae were in use among the Chinese at an exceedingly early date. They were also used by the members of the Alexandrine school as long ago as 300 B. C. But whether it may one day be possible to find a link between these two apparently independent inventions we cannot say. The Greek astronomers would certainly have been competent to discover the instrument for themselves.

Hipparchus and his followers made use of a complicated form of armilla, called the zodiacal armilla by Tycho. It consisted of six circles, of which the outermost represented the meridian and was capable of being temporarily fixed in the plane of the meridian on a stand or cradle.

The following description of the Zodiacal Armilla is given by Dreyer in his *Tycho Brahe*, p. 315.

On the inner rim it was furnished with two pivots, representing the north and south poles, on which turned a slightly smaller circle, the solstitial colure, to which was fixed immovably and at right angles another of the same size, representing the ecliptic. The colure was furnished with pivots representing the poles of the ecliptic, and on these turned two circles, one larger than the colure, another smaller than it, while the latter enclosed a sixth circle, which could slide inside it, and was furnished with two sights diametrically opposite to each other.

With this instrument differences of longitude and latitude could be measured, the circles being divided to one-sixth of a degree, while half that quantity could be estimated. It was of course a large, fixed instrument, and not a small portable one like the more modern European ones. The Arabs and Tycho also used large Armillary spheres.

The highly technical skill of their brass workers furnished the Arabian astronomers with armillae and astrolabes of great perfection. The construction and use of the instrument were described by Messahallah, who lived about A.D. 770. Observations were made with it by Ibn Junis, Abul Wefa, and others.[1]

In the armilla of Abul Wefa there were only five circles, the smaller latitude circle being crossed diametrically by a pointer or by a tube carrying the sights.

Alfonso X, the Astronomer, caused an armilla to be constructed, perhaps as an aid in the work of constructing the celebrated Tables (1272). It is described in a very clearly written MS. entitled *El libro de la fabrica et composicion del instrumentum delas armillas; el qual fue fecho por mandado del rey don Alfonso el Sabio, rey de Castilla.*[2] It is illustrated with diagrams having reference to the divided rings of an armillary sphere.

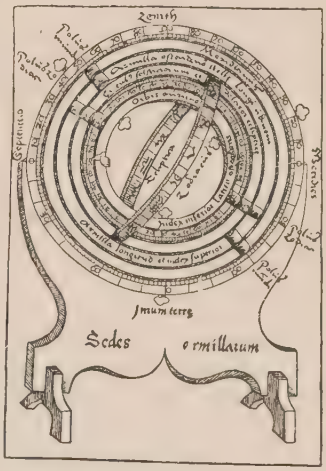
Armillae were in use in China very early and probably before the Alexandrian astronomers commenced using instruments with graduated circles. Sse-Ma-Tsien about the year 100 B.C. mentions some old instruments with

[1] Sédillot, *Mémoire sur les instruments astronomiques des Arabes*, 1841, p. 198.

[2] Bodl. MS. Canonici 340. Spanish, sixteenth century. *Incip.* 'Dixo el Sabio Abuzach Azarchel'. The MS. of 44 pages is so clearly written that it might be photographed and printed.

circles of 2 ft. 5 in. diameter. By these the motions of the stars were referred to the Equator, for there was said to have been no instrument in use for observing the motion on the ecliptic. This would seem to indicate that these wonderful people (who in so many respects were behind the Greeks in their knowledge) had actually invented equatorial armillae (which were not in use in Europe before Tycho Brahe), and used them instead of the less convenient and unsymmetrical 'armillae zodiacales' invented by Hipparchus and still used even by Walther and Regiomontanus.

Again later on, in 1279, Ko Show-King, astronomer to the enlightened Mogul Emperor Koblai Khan, erected an equatorial armilla, designed by the Persian astronomer Gemal-ed-din, that anticipated Tycho Brahe's instrument by three centuries. This wonderful old instrument with one other was removed to make room for the six new instruments constructed by Father Verbiest in 1673, but was preserved behind a window 'close set with iron bars', and has since been seen by several Europeans.[1]



ASTROLABIUM ARMILLARE OF REGIOMONTANUS, *c.* 1470.

In Europe zodiacal armillae were used exclusively by Walther, but certain defects in their construction, notably a lack of perfect symmetry, great complexity of construction, and consequent inaccuracy due to unequal strains, were pointed out by Tycho Brahe.

In later years zodiacal armillae were adapted for use as sundials and as astronomical models of considerable educational value. Three very fine models of this kind, made by Rowley early in the eighteenth century, were bequeathed to Christ Church by Lord Orrery, p. 266.

[1] J. L. E. Dreyer, 'Instruments in the Old Observatory at Pekin', *Proc. R. Irish Acad.*, iii, 1881, p. 468.

In the sixteenth century small armillary spheres were brought out from the comparative seclusion of the observatory into the wider world of practical exploration. It was a time when all science was being laid under contribution for ideas and instruments that might improve the art of navigation. And the armillary sphere, more particularly in Spain, was described by several of the authors of the manuals of Nautical Instruction that were then appearing in quick succession, but are now exceedingly rare, to assist the seamen in that age of great discoveries.

Chief among these was the *Breve compendio de la Sfera, y de la arte de Navigar*, by Marten Cortes of Bujaraloz, 1556, which was first translated into English by R. Eden and in 1609 was enlarged by J. Tapp. Cap. xi is entitled *d'la coposicio y uso d'un instrumento porel 9 Sphera.*

To this revival of knowledge of the importance of the Sphere do we owe the fine Armilla in the Bodleian Library.

60. Ptolemaick Armillary Sphere. **c. 1595.**

Bronze. 2 feet in diameter. Bodleian Library.

Supported by three lions sitting on a triangular base, engraved with the coat of arms and quarterings, crest, and badge of Henry, ninth Earl of Northumberland (1564–1632).

According to the Bodleian Benefactors' Book, a *Sphaera aenea* was presented by Sir Josias Bodley in 1601 together with a *Quadrans Astronomicus aeneus*, see vol. i, p. 382. But although presented in 1601, by the Founder's brother, it remained with many other things in Sir Thomas Bodley's house in London and did not reach Oxford before 1613.

> 27° Mar. payed for bringing ye iron chest and ye brazen sphere from London. 0–2–0[1]

By a coincidence 1613 was the year of the Earl of Northumberland's bankruptcy and imprisonment (*D. N. B.*).

Uffenbach noted on 19 Aug. 1710 that it was standing

[1] *A Book of Accompts for ye Librarie since Sr Thomas death A° 1613.* Bodl. MS.

NO. 60. THE EARL OF NORTHUMBERLAND'S ARMILLARY SPHERE C. 1595

Bodleian Library

on a wooden stand in which there was a cupboard in which the 'golden Quadrant' was kept.

The instrument comprises 3 rings surrounding a centrally placed Earth. The stand is engraved with the names of the 4 cardinal points—SEPTENTRIO . MERIDIES . OCCIDENS . ORIENS—and was probably orientated by a compass in the cavity in the middle of the foot, but the compass is now missing.

The outermost ring, which is the meridian circle, is divided into degrees with 4 quadrants numbered 0–90 and 90–0 both ways, and can be adjusted in the stand for latitude. Its poles are inscribed *Polvs Arcticvs*, *Polvs Antarcticvs*. Inside it is the ecliptic band, engraved with the signs of the zodiac and with a scale showing the corresponding days of the month. The first point of Aries coincides with 10½th of March.

The two other rings are pivoted to it with their axes at right angles to each other. The middle (equatorial) ring is fixed at right angles to the first circle: the innermost, or declination ring, is traversed by the polar axis on which the terrestrial globe revolves.

By the use of this instrument all the ordinary problems relating to the position of the sun at various seasons, that can be solved by the Globes, may also be solved.[1]

The age of the instrument is presumably settled by the coat of arms, surrounded by the Garter, on the base, which appears to have eluded the vigilance of the author of the *Annals of the Bodleian*. It is the coat of Henry Percy who succeeded to the Earldom of Northumberland in 1585. He was a buyer of works of art, interested in astrology and alchemy, and the owner of a crystal globe. His indulgence in scientific experiments gained for him the sobriquet of 'the Wizard Earl'. His other attainments are given in the *D. N. B.*, but it is important for the history of our Sphere to note that on 23 April, 1593, he was installed a Knight of the Garter. In 1600, after 5 years of somewhat troubled married life, he took part in military operations in the Low Countries, but Politics seem to have been his predominant occupation until 30 Aug. 1605, when he was created M.A. at Oxford, and proposed to lead a retired life at Syon House, with

[1] Edw. Wright, *Description and Use of the Sphere*, 1613.

his books and his science. He had, however, made too many enemies. The 'gunpowder plot' led to his being sentenced to pay a fine, to be removed from all offices, and to imprisonment for life. On appeal the fine was reduced to £11,000 (paid 13 Nov. 1613) and the imprisonment to 7 years.

In the Tower Northumberland passed his time in studies in which he was assisted by several paid assistants. Nicholas Hill aided him in experiments in astrology and alchemy, the 'three magi' Hariott, Warner, and Hues helped with their mathematical lore, and there was a fair library of Italian books on fortification, astrology, and medicine.

At what time, then, would the Earl have been likely to have disposed of his Sphere?

Clearly not in the early period when he lost much money by gaming, for he was not then a Knight of the Garter. Nor, considering the enduring nature of his scientific tastes, is he very likely to have disposed of it in 1605–13 when he was engaged in scientific pursuits. The year of his departure for Flanders, 1600, with the consequent need of raising money to defray the great expenses of such an expedition, would have been a more likely time for realizing some of his property.

Armillary Sphere Sundials

61. Armillary Sphere Sundial. **17th or 18th cent.**
Merton College Garden.

Gilt. Diameter 2 feet.

Mounted on a square stone pedestal.

Armillary Sphere Sundial. Figured by Loggan, **1688.**
Above the battlements of Brasenose College.

This may have been nothing more than a brightly painted or gilt ornament on the eastern front of the College, but it is more likely that it was originally intended to serve as a time-piece.

62. Armillary Sphere Sundial. **18th cent.**
The President's Garden, Magdalen College.

'F. C. Nehr Fecit Greenwich.'

Presented to the College in 1890 by the Ven. Charles Burney, Archdeacon of Kingston-on-Thames.

Equatorial Armillae

The invention of the equatorial armilla has been attributed to Alhazen, to Gemma Frisius, and to Tycho Brahe. Those made by Gemma Frisius[1] were portable instruments of very small size, suitable for holding in the hand.

Tycho's equatorial instruments were on a far larger scale. Two were mounted in the northern and southern observatories of Uraniborg; the third, mounted in a subterranean crypt of Stjerneborg, consisted of a declination circle 9½ ft. in diameter and a semicircle which represented the part of the equator below the horizon.

Armillae were superseded by mural or meridian quadrants, which had the great advantage of stability.

Universal Astronomical Ring Dials

A metal ring represents the meridian, and is suspended by a small ring and shackle adjustable for latitude. Pivoted to the meridian ring, so that it will fold within it when not in use, is a second or equatorial ring, divided into hours. In the position of the polar axis is a metal plate with a longitudinal slot in which slides a block with a pin-hole in it. This being adjusted for the sun's declination by means of a scale on the plate, and the instrument suspended with its meridian circle in the meridian, the rays of the sun passing through the pin-hole will fall on the hour on the equatorial circle.

The Universal Ring Dial was described by W. O[ughtred] as a 'General Horologicall Ring'. In 1652 they were 'made in brasse by Elias Allen dwelling over against St. Clements Church without Temple Barre, at the signe of the Horseshoe neere Essex Gate'. (Advertisement at the end of W. O.'s treatise on the Double Horizontal Dial.) A good figure of such a dial is given in the plate facing p. 618 of Leybourn's, *Cursus math.*

63. Universal Astronomical Ring Dial and Quadrant.

Brass. Diameter 6 inches. Ashmolean Museum.

The alternate quadrants of the outer ring are divided

[1] Gemma Frisius, *Tractatus de annulo astronomico*, 1534.

on the front side into degrees for use in north or south latitudes. The hour circle is divided to $\frac{1}{4}$ hours. The quadrant is divided and numbered on the outer circle only. Workmanship poor.

Ring and shackle for suspension missing.

ELIAS ALLEN'S UNIVERSAL RING DIAL, *c.* 1620.
L. Evans collection.

64. Universal Astronomical Ring Dial and Quadrant.

Brass. Diameter 5 inches. Pitt-Rivers Museum.

The adjacent quadrants are divided for use in north or south latitudes. The hour circle is divided to read to 5 minutes. The quadrant is divided on the outer circle but the degrees are numbered on the inner one. Workmanship excellent.

Division of adjacent quadrants as in last.

NO. 63

NO. 48 47 43 42 NO. 39

63–4. *a–d.* UNIVERSAL ASTRONOMICAL RING DIALS

42–8. *e–h.* RING DIALS. 39. *i.* COREAN SUN CLOCK

Ashmolean and Pitt Rivers collections

(*b. R. T. G. collection*)

Universal Astronomical Ring Dial.

Silver. Diameter 3 inches. R. Gunther Coll.

By Butterfield, Paris.

With latitudes of Paris 48° 51′, Aix 43° 31′, Arras 50° 11′, Grenoble 45° 13′, Basle 47° 42′, Montpellier 43° 37′, Brest 48° 23′, Cologne 50° 52′, Cambray 50° 5′, la Rochelle 46° 11′, Strasbourg 48° 42′, Lisle 55° 33′, Rome 41° 54′, Hambourg 53° 43′, le Liege 50° 38′, Nancy 48° 30′, Nantes 47° 13′, Bordeaux 44° 50′, Calais 51°, Lion 45° 46′, Londres 51° 31′, Dublin 53° 13′, Vienne 48° 22′, Gennes 44° 27′, Venise 45° 33′.

Makers of Ring Dials

The following names and dates of makers of Ring dials have been noted by Mr. L. Evans, and specimens of the work of most of them are contained in his collection.

Elias Allen, see vol. i, p. 174.
Hilkiah Bedford, clockmaker, 1667. In 1674 'of Fleet St. near Fetter Lane End at Holborn Conduit'. (Van Etten, *Recreations.*) Maker of a 5¾ inch ring dial (L. E.).
Butterfield, of Paris, *c.* 1680.
Choizy, *c.* 1740, Paris.
John England, *c.* 1730. Maker of a Universal Ring dial marked 'I. England Fecit' (L.E.).
R. Glynne, *c.* 1705–55. 9½ in. ring dial (L.E.).
John Hancock, *c.* 1740. A well-known maker.
Joseph Jackson, 1740–50. See vol. i, p. 185.
T. Jones, *c.* 1800. (L.E.)
G. Meureus, of Rome (?), *c.* 1590–1620.
J. A. Pfeiffer, of Coburg, *c.* 1717.
Charles Proctor, *c.* 1780. 'Proctor Bros. Milk St., Sheffield.'
L. Proctor, *c.* 1740.
J. C. Rothknecht, of Salzburg, *c.* 1720.
Franc. de Salvis, of Rome, 1695.
H. Sneewins, of Leyden, 1660.
Johann Sommer, of Augsburg (C. Fry).
T. W., *c.* 1730.
J. H. Weyerman, of Ronsdorff, 1747.

Universal Astronomical Ring Dial. c. 1670.

Vernon Watney Esq., Cornbury Park.

'*I. Marke fecit*'.

Diameter 18 inches. Mounted on a bronze support as a garden dial. A magnificent instrument. Marke succeeded Henry Sutton. *See* vol. i, p. 178.

QUADRANTS

The Quadrant is essentially an instrument for measuring angular altitudes by a line of sight or shadow and a plumb-line, but even in quite early forms of the instrument, tables, scales, dials, &c., were added to serve the purposes of the analogous apparatus upon the astrolabe.

The Quadrant differs from the astronomical ring in being only a quarter of a circle, and instead of being suspended from one point is held in the hand or on some other support so that the sight holes in two vanes on its edge are brought in line with the object. From the centre of the graduated arc hangs a plumb-line, which is held against the arc after the sights have been brought on the object. The position of the plumb-line shows the altitude.

Quadrants for astronomical purposes may be conveniently classified as Observatory Quadrants, and as Portable or Hand Quadrants.

1. Observatory Quadrants

Ptolemy described a meridian quadrant attached to a cube of stone or wood, with a small cylinder in the centre of the arc, of which the shadow indicated the altitude of the sun on the graduation.

Delambre[1] doubts whether Ptolemy ever used an instrument of this kind, as he only quotes one observation with it, the difference between the sun's altitude at the two solstices, for which he gives exactly the same value as had been found by Eratosthenes.

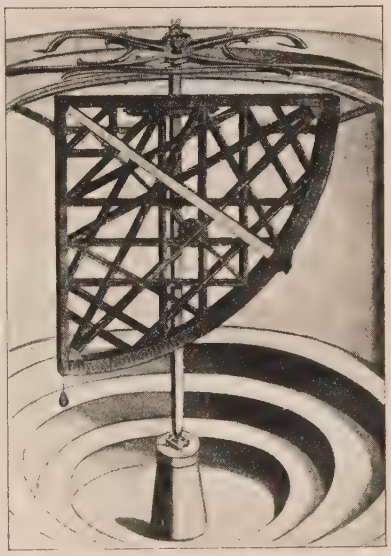
A great quadrant of 21 ft. radius is said to have been erected by Al Sagani about A.D. 995, and about 1259 Nasir ed din Tusi included a Ptolemean mural quadrant among the instruments for his fine observatory at Maragha. This instrument was made of hard wood and with a radius of 12 ft. The limb was of copper, on which three arcs were drawn; the middle one was divided

[1] *Astronomie ancienne*, ii, p. 75.

into degrees, while of the others, one showed every fifth degree. A two-sighted alidade turning about the centre was moved by a cord passing over a pulley. Nasir ed din mentions the instrument of Ptolemy.

Another instrument in the Maragha observatory was fitted with two quadrants turning on a common vertical axis within an azimuth circle. Two objects could thus be observed by two astronomers at the same time and their altitudes and difference of azimuth found.

For measuring altitudes Tycho Brahe[1] favoured azimuthal quadrants, of which he constructed four. The largest instrument, his *quadrans magnus chalibeus*, was enclosed in a square (also of steel) of which the side was equal to the radius of the quadrant. Two of the sides were graduated, and the alidade pointed to these graduations as well as to those on the arc, so that the instrument was a combination of a quadrant and the 'quadratum geometricum' of Purbach (which the Arabians had also known), which increased the solidity of the instrument.



TYCHO'S 'QUADRANS VOLUBILIS AZIMUTHALIS', *c.* 1587.
From Blaeu's *General Atlas*, Amsterdam, 1664.

The figure is of interest because it shows the large number of cross braces and stays which were necessary to secure rigidity in the construction of these large instruments, and which in a modified form were such a feature of the large Oxford Quadrants by Bird.

We have no observatory quadrants in Oxford of the

[1] Tycho's instruments are described in *Astronomiae Instauratae Mechanica*, 1598.

pre-telescopic period. The oldest Oxford instruments are the small Gunter's quadrant of ivory, mounted on a stand by Rowley (p. 179), and the fine pair of 8-foot quadrants made by Bird for the new Radcliffe Observatory in 1771–3. (See p. 321.)

As instruments for the refined measurement of angles, quadrants held the field until John Pond, Astronomer Royal 1811–36, substituted entire circles for them.

Mural Quadrant of 6-foot radius
Brass Quadrant of 3-foot radius
Brass Quadrant with telescopes } 1697.

Presented by J. and T. Greaves to the Savilian Museum for the use of the Professors, but not now extant. See p. 79.

2. Portable or Hand Quadrants

The early history of the hand quadrant as an astronomical instrument was involved with that of the quadrant, or quadrate, of the land surveyor or geometrician; and many instruments were constructed to serve both purposes. It is common sense to assume that the surveyor's quadrant was the older instrument of the two.

A practical surveyor is more concerned with the lengths of straight lines than with the values of angles. His quadrant in early days was marked with two scales at right angles, drawn perpendicular to the sides of the quadrant, and divided into equal parts. When referred to these scales the plumb-line of the instrument will give not the angle of inclination of the line of sight to the horizon, but the trigonometric tangent of this angle, if it be less than 45 degrees, or the cotangent if it be between 45 and 90 degrees. The method of using such an instrument was described by Leonard of Pisa in 1220. See vol. i, p. 338.

In ordinary quadrants the radius or side of the square is divided into 12 parts, and the tangents or cotangents measured in these parts are called 'umbra versa' or 'umbra recta', respectively, terms which recall the Arabian origin of the instrument.

To such a simple instrument the astronomer has added accessories for his own purposes. By direct observation he can measure the altitude of the sun, and

then by his solar Tables find for each day in the year the place of the sun in the ecliptic, and by his solid, or armillary sphere, he can bring the sun's place into correspondence with the measured altitude, then take the angle of the hour circle with the meridian. The latter operation could also be performed by the Greek planispheric astrolabe, which being portable enabled the astronomer to dispense with the more cumbrous sphere. The problem was whether a quadrant, by which the sun's altitude could be more accurately measured, could not also be used as conveniently for obtaining the time.

The works of JOHN OF MONTPELLIER give a very ingenious solution to this problem. Hour lines are engraved on the face of the quadrant and the plumb-line is furnished with an index in the form of a bead that slides somewhat stiffly. Having ascertained from the Tables the sun's declination for the particular day of the month, it is to be subtracted, if it be southerly, from the colatitude of the place of observation; or, if it be northerly, it must be added. The plumb-line is then placed on the degree given by this calculation and the bead is adjusted to the hour line of 12 noon; then, by holding the quadrant vertical and pointed to the sun, the hour of the day can be read by the position of the bead on the hour lines.

An instrument of this nature is engraved on the back of the oldest Oxford astrolabe, belonging to Oriel College.

81. Horary Quadrant and Astrolabe. c. 1340.

$9\frac{6}{10}$ inch radius. Oriel College.

The limb is divided into 90° along the circumference of the circular back of the plate, thus giving the quadrant an effective increase of radius to 12 in. and allowing space on the limb for graduation to $\frac{1}{2}$-degrees. The plummet-line was suspended from a small hanging arm or *brachiolus*.

On the inner curved quadrantal arc are the scales of the shadows. The divisions are numbered 3 · 6 · 9 · 12 · 9 · 6 · 3, to which the marginal notes *d' minor* and *d' maior* refer.

Within the quadrant are lines of an *instrumentum horarum inaequalium*.

The possible connexion of this instrument with SIMON BREDON is discussed on p. 208.

82. Horary Quadrant. c. 1350.
Merton College.

See p. 208.

Similar to the last: both instruments required Tables.

The next step was to dispense with the Tables and thus to give the quadrant a marked superiority over the astrolabe, for which Tables were always necessary. To obtain the time without Tables an addition to the quadrant was required, in the form of a sliding piece or 'cursor', by which the declination of the sun on the day of observation is found mechanically.

A cursor, formed by an arc of amplitude equal to that of the arc of the meridian between the tropics (double the obliquity of the ecliptic), slides along the limb in a groove concentric to it. The mid-line of the cursor, = 0, is used as the starting-point for measuring any arc on the cursor in degrees on the outer limb. The cursor is divided for Days of Month, Signs and Degrees.

If then the zero of the cursor be adjusted to the degree on the limb marking the colatitude of the place, the subtraction or addition of the declination is effected automatically. One has only to place the plumb-line on the division corresponding to the day of the month and to proceed as if with an instrument without a cursor.

The combination of hour-lines with scales of the shadows, or of an horary with a surveying or geometrical instrument, gave rise to the **Old Quadrant** or Composite Quadrant. By the further addition of a zodiac band, of some star positions, and of appropriate scales, the instrument became a **New Quadrant** or Astronomical Quadrant. The earliest mention of the instrument is to be found in an eleventh-century work, *De utilitatibus astrolabii*,[1] variously attributed to Hermannus Contractus, or to Gerbert, the source of which is obviously indicated by the Arabic words in the text. The quadrant described was already furnished with a *cursor*, and the principle of finding the hour was peculiar.

[1] Printed in Pez, *Thesaurus*, 1723, and in Migne, *Patrologia*, v, bk. 2. An early Arabian Treatise of the Quadrant by Al Majdi is in the British Museum.

In the thirteenth century treatises on the construction and use of the quadrant became fairly common.

Several of the copies of the *Treatise on the Quadrant* are illustrated with well-executed figures of the instrument which leave no doubt as to the details of its construction. None of the various authors or transcribers of the many versions of the Treatise give themselves out as the actual inventors of the instrument, or even as being responsible for the arrangement of its parts. We may therefore assume that it had come to them from earlier generations in as complete a state as that in which they found it, and that their work has merely been that of description, of compiling text-books for the use of their Latin-reading pupils who might know no Arabic. In the absence of definite information as to the inventor, it is convenient to distinguish the various types of the instrument by the name of their describers.

One of the first of these illustrated descriptions of the Old Quadrant in Latin was compiled by John Halifax or Johannes de Sacrobosco.

JOHANNES DE SACROBOSCO, *c.* 1220–44,[1] realizing that the study of astronomy had almost been given up owing to the difficulty of procuring the works of the ancient writers, wrote a small work on the Construction of the Simple and Composite Quadrant, and on their uses. A similar treatise is ascribed to Campanus. But the best accounts of the instrument are those of a writer who is generally known by the name of JOANNES ANGLICUS OF MONTPELLIER, though his latest editor, M. Paul Tannery,[2] will have it that Jo. Anglicus is a mistake for Ro. Anglicus and that ROBERT ANGLÈS was the real name of the master.

Sacrobosco's Quadrant. c. 1230–40.

Figure copied by Delambre, fig. 54, from the fourteenth-century MS. Bibl. nat. Paris lat. 7196, ff. 25–27^{b}.

'Tractatus magistri Io. de Sacrobosco super compositione quadrantis simplicis et compositi et utilitatibus utriusque et.' Beg.: 'Omnis scientia per instrumentum

[1] Sacrobosco is usually stated to have died in 1256 but Tannery quotes a verse giving 1244 as the correct date.

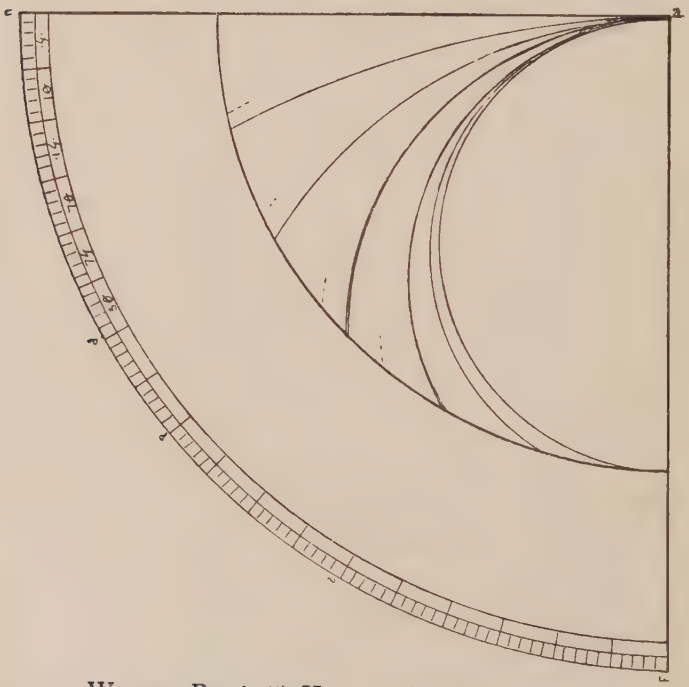
[2] Paul Tannery, *Le Traité du Quadrant de maître Robert Anglès (Montpellier, xiiie siècle). Notices et extraits des MSS. Biblio. nat.*, xxxv, pp. 560-640. Paris, 1897.

operativa.' Ends: 'et hec michi dicta de simplici et composito quadrante sufficiant.'

On the cursor the graduated arcs of the Signs are arranged between the arcs of the Months and Days, whereas in the cursor of the quadrant of John of Montpellier they are above and below the arcs of the Months and Days.

Horary Quadrant. **xiii cent.**

Next in date may be the work[1] of an anonymous Oxford author written in a thirteenth-century hand



WALTER BRIT'S (?) HORARY QUADRANT, 1395.
To illustrate the Liber Quadrantis of the 13th century.
MS. Digby 98, *ff.* 162–5, *with tables for the latitude of Oxford,* ff. 164, 164v.

beginning 'Cum quadrantem componere volueris accipe tabulam eneam vel ligneam bene politam', followed by

[1] MS. Bibl. nat. Paris. lat. 7416 B, ff. 62–4.

a note of the latitudes of Oxford and Paris in the same hand. I do not know whether or not this is illustrated, but the *Liber Quadrantis; cum tabulis ad meridiem Oxon*, with a similar beginning, MS. Digby 98, f. 162, has a figure of a quadrant of $5\frac{1}{2}$ in. radius on f. 165.

This quadrant has an instrumentum horarum, but neither scales of umbra recta and umbra versa, nor a cursor. The MS. was written in 1395 by a Merton man—WALTER BRIT is suggested by Macray—and contains a second treatise *De Compositione et officio quadrantis*, f. 148b.

Inc. 'Post compositionem chylindri nunc cujusdam instrumenti horologici, viz quadrantis compositionem investigemus.'

Expl. 'Hec quoque breviter dicta de practica quadrantis causa introductionis sufficiant ad praesens. Completa Oxon. in domo Scolarium de Merton tempore superioris annotato. (A.D. 1395.)
Explicit *tractatus de practica quadrantis* quod Partrich.'

Of this work an older copy, *c.* 1282, may be consulted in a small 16mo MS. Digby 2, ff. 112–20, but it does not contain figures.

John of Montpellier's Quadrant. Figure dated **1276.**
Radius 6 inches. MS. Ii. 3. 3, f. 57 b. Cambridge.

An excellent drawing of a quadrant in every way similar to Sacrobosco's instrument except in the trifling detail of the arrangement of the arcs upon the cursor. The title of the book is *Tractatus Quadrantis* 'editus a Magistro Johanne in Monte Pessulano'.

John of Montpellier's Old Quadrant. **Before 1350.**
Radius $5\frac{7}{8}$ inches. f. 72, MS. Ashmole 1522.

An excellent figure, accompanied by diagrams showing how the quadrant was used.

The vane sights are pierced with both large and small foramina. The beginning 'Incipit *Tractatus quadrantis veteris* secundum magistrum Iohannem in Monte Pess' is interesting on account of the introduction of the word 'veteris' that does not occur in the Cambridge MS. of 1276.

John of Montpellier's Old Quadrant. 1437.

Radius $4\frac{3}{4}$ inches. f. 117, MS. Bodley 472 (S. C. 2492).

A roughly executed figure by Tristrandus of Louvain, 1437.

Tannery enumerates eleven MSS. on this Quadrant in the Paris Library. All begin 'Geometriae duae sunt partes theorica et practica'. Four of them are catalogued under the name of Ioannes de Montepessulano, one under Robertus Anglicus, two Ioannes Anglicus, while four are anonymous. In Oxford, in addition to MS. Ashmole 1522, we have anonymous copies in MS. Univ. Coll. No. 41, MS. C.C.C. No. 41, and MS. Digby 147.

The identity of John *alias* Robert is not easy. Tannery suggests that he was distinctly not an Oxford professor who had accidentally visited Montpellier. He may have been born in England but have settled in Montpellier, or even have been the son of a Guillelmus Anglicus, an astronomer of Marseilles, 1231.

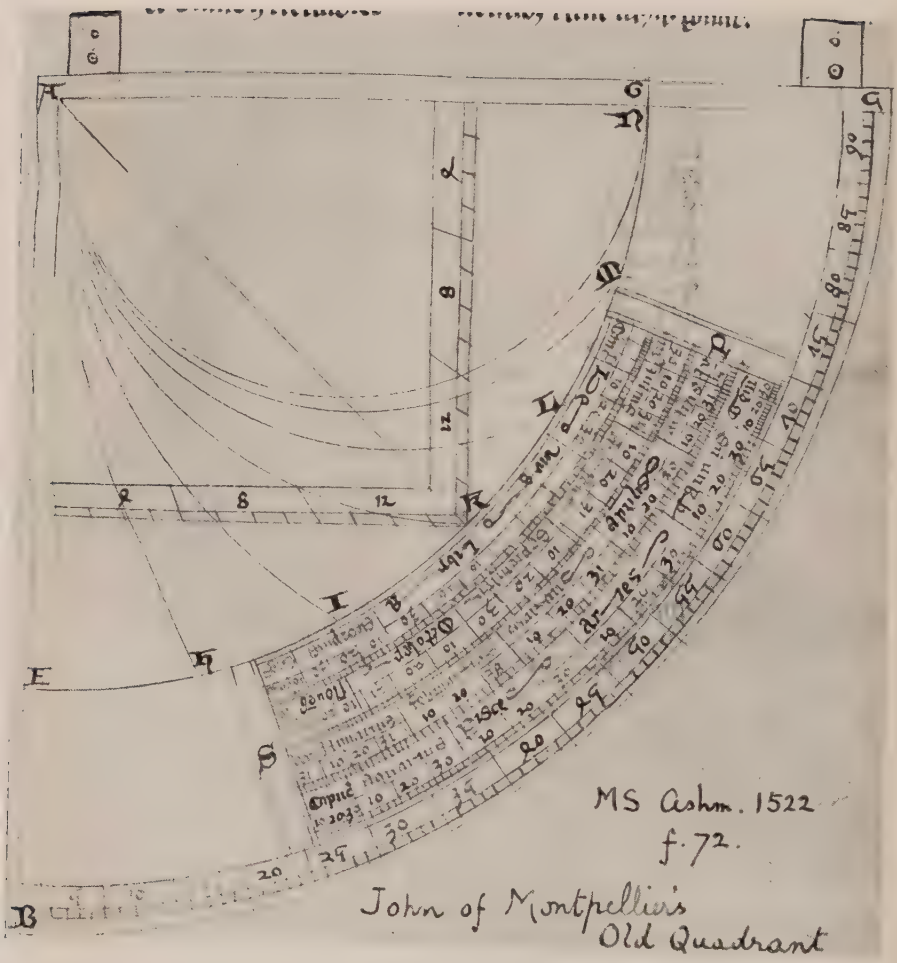
Tannery, having arrived at the conclusion that the instrument was invented some time before the period of Robert Anglicus, has endeavoured to arrive at its probable date from the evidence of the Tables that were used with it.

The MSS. are accompanied by Tables. The first is a *Tabula declinationis Solis que est distancia eius ab equinoctiali secundum Albategni.* The obliquity of the ecliptic is put at 23° 33′, i.e. about 2′ less than is given by authentic documents for the determination by Al-Battani. It comes much nearer to the figure of Tobit ben Korra (23° 33′ 30″): in any case it corresponds with the obliquity for the first half of the twelfth century.

Then follow four other Tables giving in degrees and minutes the longitude of the sun for every day of every month, beginning in March and ending in February. In one MS. the Tables are said to have been verified for the years 1292–5. The Vernal equinox would have commenced on 13th March at 12.35 midnight in 1295.

The Tables of another MS. appear to have been constructed for the year 1175. And in two MSS. there is a little Table for the beginning of the twelfth century.

In other words Robertus Anglicus made use of out-


MS Ashm. 1522
f. 72.
John of Montpellier's
Old Quadrant

of-date Tables without correcting them. One was for *c.* 1200; another for three-quarters of a century too early. The Tables may have been constructed for other quadrants or astrolabes of an earlier day. This suggests the second half of the twelfth century as the period of the original instruments for which the Tables were made, and such an instrument may have been in the hands of Sacrobosco and of Robert Anglicus.

The geometric part of the *Treatise on the Quadrant* may have come from such a source as is contained in MS. Digby 174, f. 145, *De altimetria.*

The term **Quadrans vetus** is most suggestive. It suggests a quadrant that had been superseded by a new invention. And we have actually found information in the Bodleian Library about a **quadrans novus**. About 1288, at Montpellier, a celebrated rabbi, Don PROFAT TIBBON of Marseilles (Jacob ben Machir), better known by his Latin name of PROFACIUS, wrote a treatise on this new quadrant.[1]

[1] Partly owing to a careful examination of the MSS. by Renan (*Hist. littéraire de la France*, xxvii, p. 599), several editions of Profacius's *Treatise* have been distinguished:

1. First Hebrew edition, written at Montpellier in 1288.

2. Latin translation by Hermigald of Blaise, at Montpellier in 1299. Of this a transcript of 1324 is in MS. Biblio. nat. Paris. lat. 7437, f. 183 b. *Explicit tractatus super opus novi quadrantis editus a Magistro Profatio Iudeo de Massilia sapiente astronomo anno Domini M° CC° nonagesimo et declaratus fidelite per suos discipulos et eius precipuos sectatores anno Domini M° CCC° vicesimo quarto.*

3. Second Hebrew edition. 1301.

4. Second Latin edition, translated from No. 3, with modifications by Petrus de S. Adamaro (= Pierre de St. Omer) is in MS. Bibl. nat. lat. 7416 B, f. 15 b: *Explicit nova editio quadrantis a magistro Profacio Iudeo Montispessulani continens omnes utilites quadrantis antiqui et etiam astrolabii.*

In MS. Ashm. 360, ff. 49-61, is the work entitled *Ars et operacio novi quadrantis editi a magistro Profacio Marciliensi . . . a Petro de sancto Adamaro Parisius diligenter correcti et perfecti.*

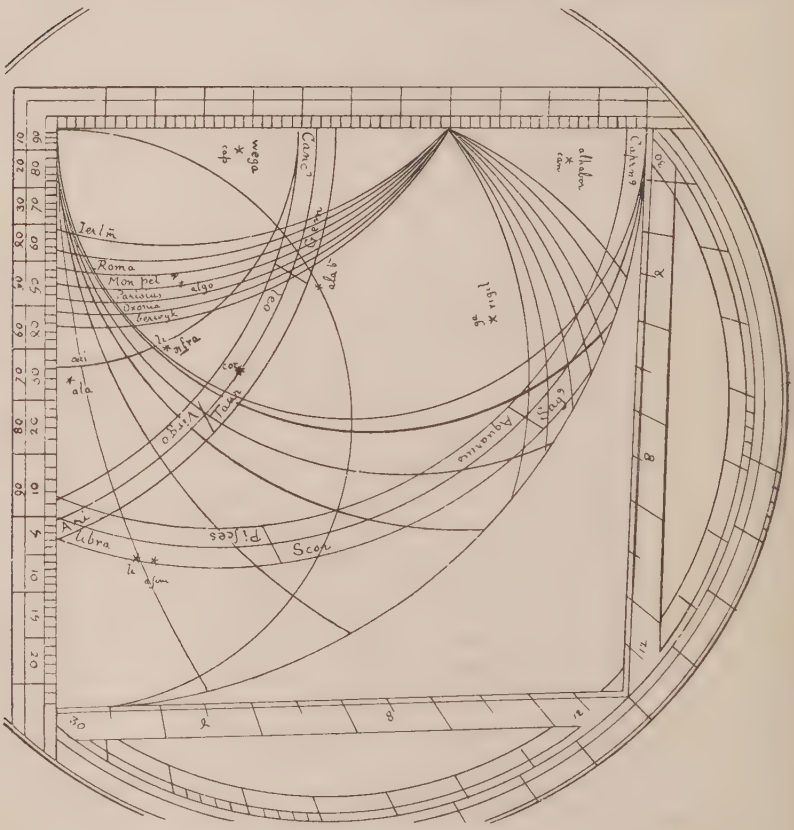
5. Third Hebrew edition, translated from No. 4 (Latin) back into Hebrew by Jews.

One of these must have been the source whence the Oxford versions were derived. The codex MS. Ashmole 1522 is proof that even before A.D. 1350 the several works on the quadrants old and new were being brought together, usually with treatises on the cylindre and astrolabe, and even as late as 1433 such a collection was made for the owner of MS. Bibl. nat. lat. 7294 which begins *Compositurus novum quadrantem accipe tabulam planam ad similitudinem quartae partis circuli factam.*

New Quadrant of Profacius. **1288–1301.**

Bodleian. MS. Ashmole 1522 (temp. Edw. II), ff. 122–132.
MS. Tanner 192, f. 109.
MS. Digby 17 (fifteenth century), ff. 160, 164.

This quadrant is figured and described in the *Tractatus Quadrantis Novi compositi a Magistro Profacio Hebreo,*

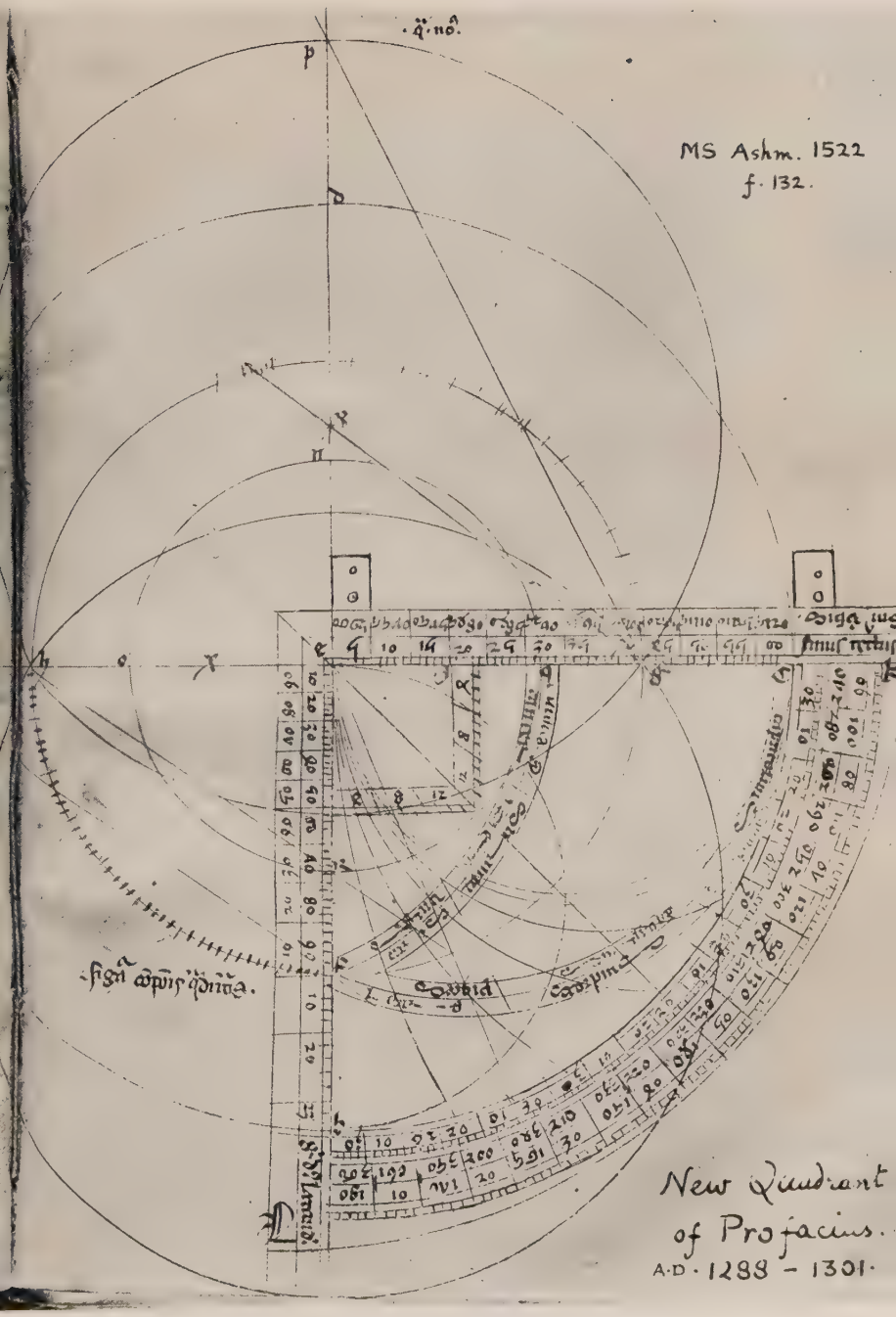


New Quadrant of Profacius, 1301.
MS. Digby 17, *f.* 160.

anno domini 1288 et correctus ab eodem A.D. *1301,* and differs in many important respects from the Old Quadrant of John *alias* Robert Anglicus of Montpellier.

Firstly the hour lines extend right across to the limb

MS Ashm. 1522
f. 132.



New Quadrant
of Profacius.
A.D. 1288 – 1301.

of the quadrant, and secondly the signs of the zodiac are arranged along two arcs which meet near one side of the instrument. Both borders are graduated in a manner that will be described in our account of the Merton instrument.

The method of constructing the lines is shown in figures in both the above-mentioned MSS., and the figures in MS. Digby 17 show lines for the latitudes of Jerusalem, Rome, Montpellier, Paris, Oxford, and Berwick.

That the works of Profacius were known to Rede is indicated by the fact that the Codex Digby 176, which was specially left by Rede for the use of the scholars of Merton and Exeter Colleges, formerly contained the Almanack calculated by Profacius (Macray).

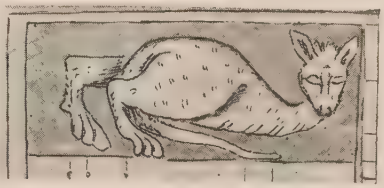
There is thus a very close resemblance between this instrument and the French quadrant to be next described.

67. New Quadrant of Profacius. c. 1301–50.

French. Bronze. Radius 1 foot. Merton College.

From the lettering this quadrant has been considered to be the oldest of the astronomical instruments belonging to Merton College, and this is confirmed by the coincidence of the first point of Aries with the 13th of March in a volvelle on the back of the instrument.

That this may be the real date of the instrument, or at any rate of the circular scales, receives further support from their resemblance to an instrument (No. I. 10) in the collection of Mr. Lewis Evans, ascribed to *c.* 1400–50. It should be noted that the engraver of the Merton quadrant does not appear to have finished his work on either side.



Rebus in corner of Merton Quadrant, *c.* 1300–50.

On the face the three corners are ornamented with designs chased in the metal, which probably had some personal significance. Two are representations of what appear to be hinds without fore limbs; one is holding a leaf-spray in its

mouth. The third design in the angle of the quadrant is almost certainly a rebus or a badge: it comprises, within a small square panel, the two legs of an animal, presumably the missing legs of the hinds, grouped horseshoe-wise round some central object: alongside is a fleur-de-lys.

The Quadrants

Two fixed sights, the fore-sight with a pin-hole and the back-sight with two grooves, are dovetailed into the top edge of the base-plate, and two perforations through the plate may have been drilled for a second pair of sights upon the face of the quadrant.

The limb has been graduated along arcs described from two centres with a difference of radius of about $\frac{3}{4}$ in. We recognize

i *a*. An outermost quadrant of $11\frac{3}{4}$ in. radius for observation of altitudes. This circle is divided into degrees grouped in fives, but they are not numbered.

i *b*. An inner quadrant of 11 in. radius. The degrees are numbered both forwards and backwards in alternate spaces from 10 to 360.

Scale of Signs of the Zodiac, numbered in alternate spaces 10, 20, 30. This scale corresponds to the Signs projected on the face of the quadrant.

The Scales

The sides of the quadrant are bordered with scales. ii. Parallel to the line of sight is a scale numbered by fives from 0 to 60 (downwards) and also in tens (upwards) in the reverse direction from, and in the alternate intervals from 70 to 110, '120' not being marked. These are scales of corda recta and corda versa respectively, the word 'corda' being used by mediaeval mathematicians in lieu of the word 'sines', which came in in the fifteenth century. They were used in connexion with the two crossing semicircles engraved on the plate.

iii. On the other side there are two scales divided in 90 parts between the centre of the quadrant and the intersection of the ecliptic with the said side: these parts increase with distance from the apex and are numbered

NO. 67. NEW QUADRANT OF PROFACIUS AND REBUSES

Merton College

NO. 77. DALECARLIAN SUN-CLOCK

Pitt-Rivers Museum

in tens. They are scales of declination; of northerly declination from 0° at equator to 90° at N. Pole and of southerly declination from 0° at equator to 23° 30′ at Tropic of Capricorn. These scales therefore give the latitude.

iv. In the angle are scales of umbra recta and umbra versa numbered 3. 6. 9. 12. 12. 9. 6. 3.

The rest of the face is filled with (v) a large instrumentum horarum. (vi) A projection of the Zodiac and neighbouring stars. Seven stars, 'Rigil, Aldebran, Alabor, Alfarat, Cor Le, Altalit, Alchimehc', are named, and there are blank spaces for four others which must certainly have been intended for Alhaiot, Vega, Altair, and Cor Scorp. The instrument therefore appears to be unfinished. The marginal scales 6–25 and 10–90 refer to this projection of the constellations near the ecliptic. In connexion with this stellar projection is a group of the five horizon lines which meet on the equator and impinge on the scale of declination at points corresponding to the latitudes 33° 30′ (Damascus), 46° (Lyons), 48° (Orleans), 49° (Paris), and 56° (Edinburgh).

On the *back* are ten circles. In order from the outside they are—

vii. 1. Circle of degrees, about $9\frac{3}{10}$ in. in diameter.
2. Numbers 10, 20, 30, for each sign of the Zodiac.
3. Names of the signs of the Zodiac.
4. Blank.
viii. 5. Circle of the mid and last days of the months inscribed over names of months in circle 6. These numbers have been misread as years and have been wrongly used to date the instrument 1430!

1531	1428	1531	1530	1631	1530
JANY.	FEBR.	MARC.	APRI.	MAIV	JVNI
1631	1531	1530	1531	1430	1531
JVLI	AVG.	SEPT.	OCTO.	NOVE.	DECE.

These circles (5 and 6) are not concentric with the others, so they were evidently used as an 'Instrumentum Theoricae Solis' like that described in Peter Apian's *Cosmographia*, f. 9, edited by Gemma Frisius in 1545.

ix. 7–10. Blank, but divided into 28 spaces. They were intended for the 28 lunar mansions[1] with figures of the corresponding asterisms. In the centre there might have been (x) a circular table for finding the date of Easter with circles of possible dates and Dominical Letters.

It is possible that card or paper disks, like those used to illustrate early text-books on the subject, may have been used in connexion with these circular scales, or else that the numbers of any desired cycle may have been written in the spaces.

Somewhat similar circular scales have been figured by Anthiaume et Soltas in *L'Astrolabe Quadrant*, Paris, 1910.

I have been able to find in the Bodleian Library a manuscript description of a quadrant which exactly corresponds to the Merton instrument. In MS. Ashmole 1522, written during the reign of Edward II, or before 1350 at latest, there are copies both of the *Treatise on the Old Quadrant* of John of Montpellier, and of the *Tractatus Quadrantis Novi compositi a Magistro Profacio Hebreo A.D. 1301.* The Merton instrument is undoubtedly the New Quadrant of Profacius.

The diagrams on p. 164 explain the method of constructing the various arcs on the face, and the use and construction of the circular scales of Signs and Months.

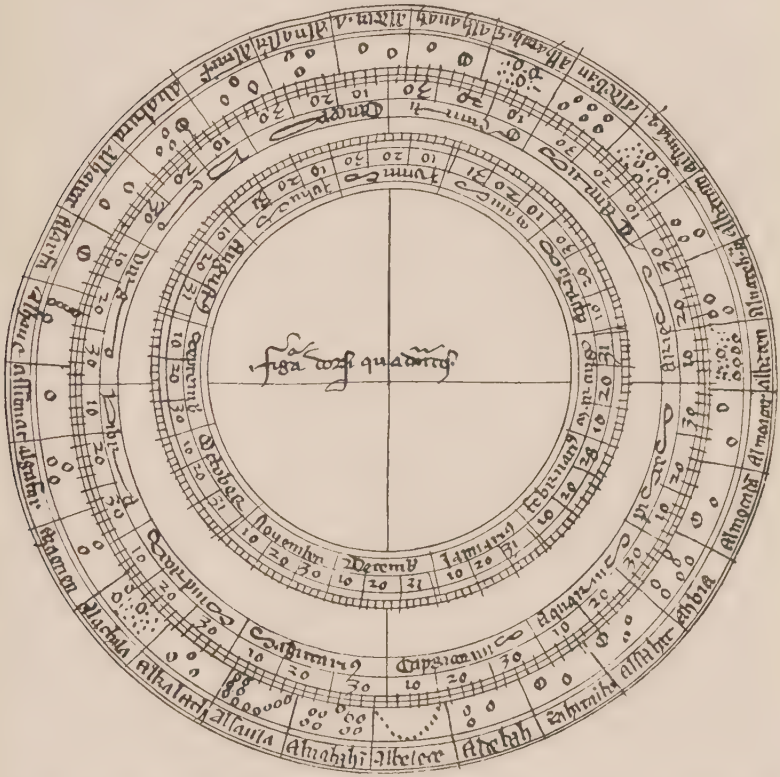
In the *figura dorsi quadrantis*, circular scales have been drawn for an epoch when the first point of Aries = 16 March.

The asterisms of the 28 lunar mansions are distinguished by name and by characteristic figures of their several stars; and although in the MS. instrument they fill the outer circles, it is not unlikely that in the Merton Quadrant they would have occupied two of the inner three circles. So far as we can read the names appear to be

1. Alnateh. p̄	8. Alnaster	15. Algafar	22. Aldebah
2. Alherain	9. Altarf	16. Azaonen	23. Sahitaibo
3. Alsuria .3.	10. Alca-bata	17. Alachala	24. Alsahac
4. Aldebran	11. Alharece	18. Alkalach	25. Ahbia
5. Athatah . ς	12. Alarfa	19. Alsaula	26. Almocadā
6. Alhanah	13. Alhaue	20. Alnahahī	27. Almoacar
7. Aldera . ^	14. Assumac	21. Albelece	28. Albaten

[1] For an early description of lunar mansions, see MS. Ashm. 360: 1. *De cursu lunae cum figura domorum.* 2. *Mansiones Lunae cum aliis.* 3. *De xxviii mansionibus liber.*

By the restoration of this astrological circle to their instrument, the Fellows of Merton College might once more take part in the occult practices that are said to be so prevalent in London at the present day.



Circular Scales for the back of the New Quadrant of Profacius. *MS. Ashm.* 1522, *f.* 131 v.

On the same page of the MS. are three small tables—1. Of longitudes and latitudes of the eleven quadrant stars. 2. Of the relation of the beginnings of the months to the Signs. 3. Of the 'elevatio signorum'.

68. Physician's Quadrant. c. 1400–50.

Circular, diameter $6\frac{1}{8}$ inches. Merton College.

A composite instrument built on a circular disk. The incised lines and figures upon the instrument are of two periods: the older being filled with red colour, the later additions with black. The rim of the disk is drilled with 72 holes, at 5° apart.

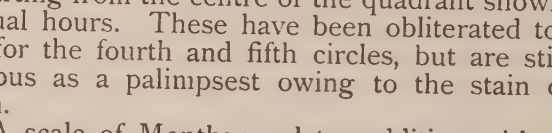
The Face.

1. A Quadrant of $3\frac{3}{4}$ in. radius. The sights (now missing) were fixed in two perforations drilled through the base plate. The plummet was suspended from a third hole. The limb is graduated in degrees numbered 15, 30, 45, 60, 75, 90.

2. A scale of umbra recta and umbra versa numbered 4, 8, 12, but partly obscured by later engraving.

3. An early type of instrumentum horarum, with arcs all starting from the centre of the quadrant showing the unequal hours. These have been obliterated to make way for the fourth and fifth circles, but are still conspicuous as a palimpsest owing to the stain of corrosion.

4. A scale of Months: a later addition with figures filled with black pigment:



5. A revised instrumentum horarum for the equal hours, constructed on the lines of the one described by Stöffler, 'Per horarium dorso Astrolabio inscriptum horas aequales et inaequales dicto citus cognoscere.'[1]

We regard this as a most interesting instance of an effort to make the instrument up-to-date. We have been fortunate enough to find in the Bodleian a manuscript MS. Ashm. 19, f. 54, which may have been the very figure from which were taken the alterations to the instrumentum horarum. A brass quadrant with a similar set of hour lines was made for Richard II in 1399 and is now in the British Museum.

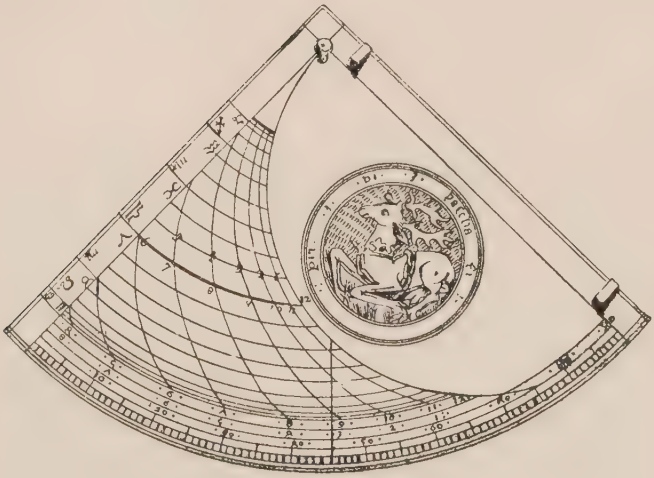
6. Below the quadrant is a human figure posed by an artist with some knowledge of drawing. The man has long hair and a stubbly beard, and he is covered with

[1] Stöffler, *Fabrica Astrolabii*, 1535, f. 28.

NO. 68. PHYSICIAN'S QUADRANT AND ZODIAC MAN

Merton College and MS. Lib. Mus. Ashm. A 5

MS. Ashmole 19, *f.* 54.



QUADRANT MADE FOR RICHARD II, 1399.
Evans, Portable Dials, Scale $\frac{2}{3}$.

signs of the Zodiac, each on an appropriate part. It is an example of the way in which the later astrologer-physicians made use of the constellations of the zodiac, exactly as the Greeks had employed the planets, for predicting the fate of an individual, and more particularly for finding the auspicious times for blood-letting.[1]

According to the usual scheme

ARIES is sitting on the head.
TAV is behind the neck.
GEI are in the arms.
CAN is over the heart.
LEO is on the lower part of the chest.
VGO is on the stomach.
LIB are on the buttocks.
SCOR [6-legged] is over the pubis.
SAG is on the thighs.
CAP is on the knees.
AQ between the legs.
PI PIS under the feet.

Galen is credited with a statement which would seem to embody the errors of both planetary and zodiacal systems of influence. 'If the patient takes to his bed when the moon is in Aries, and in position with Mars or the sun, the disease will be in the head.'

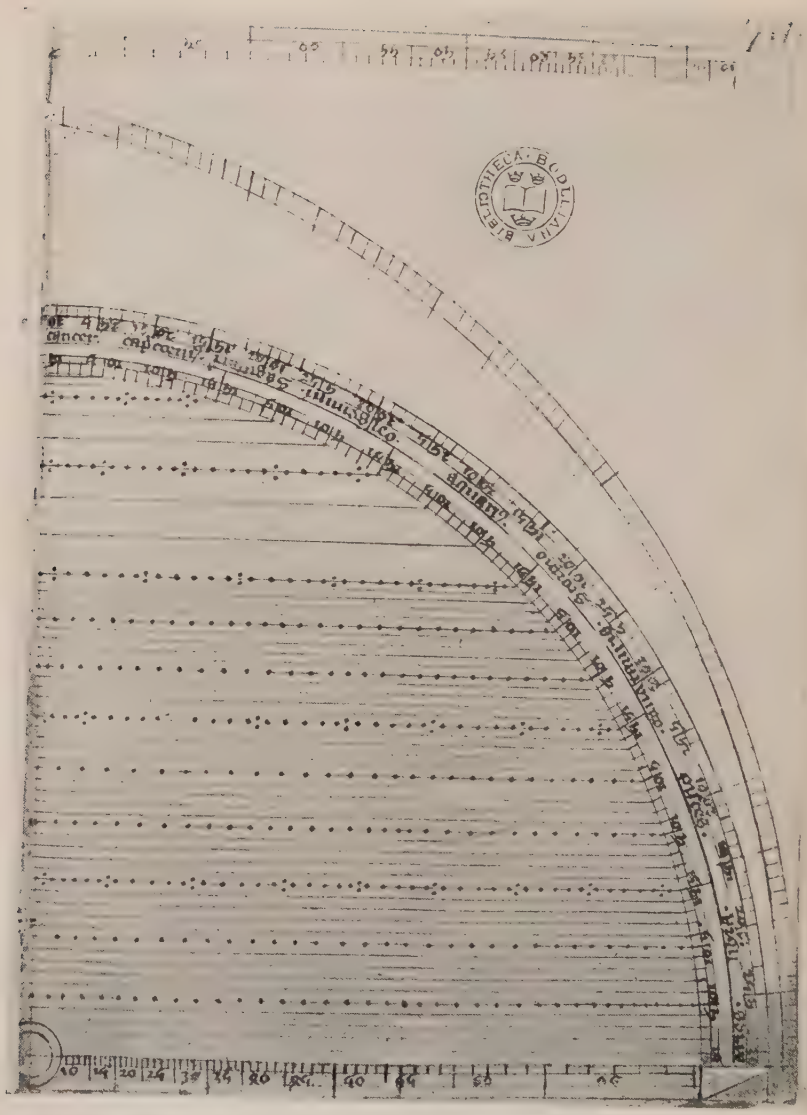
On the *back* is the volvelle described on p. 240.

SINECAL QUADRANTS

Early Sinecal quadrants are almost invariably present on the backs of oriental astrolabes, and may have been introduced to western science through the translation into Latin of the *Astronomia* of Geber by Gerard of Cremona (1114-87). This translation was printed at Nuremberg in 1534, and doubtless suggested the use of instruments and tables of sines to Peter Apian (1495-1552) and to Orontius Finaeus who both applied the geometrical knowledge involved.

Apian, *Instrumentum sinuum sive primi mobilis*, 1534; Finaeus, *De Mundi Sphaera*, 1542.

[1] Elaborate pictures of the Zodiac man are printed by Stöffler in his *Calendarium Romanum*, 1518, f. 14, and by L Digges in his *Prognostication* with 'A conducible note for letting Bludde', f. E of the 1555 or f. 19 of the 1564 edition.



SINECAL QUADRANT, C. 1400

MS. Bodley 68, f. 48

Sinecal Quadrant. **? xvth cent.**

Wood : 8-inch radius. Royal Society.

A very roughly made instrument of uncertain age and provenance, but eminently worthy of being carefully preserved on account of its great antiquity.

The rim is graduated into degrees grouped in sixes.

The field is ruled with 28 parallel lines at about $\frac{1}{5}$ inch apart.

Sinecal Quadrant. Date of figure **c. 1400.**

MS. Bodley 68 (S. C. 2142), f. 48.

The carefully executed drawing shows a graduated rule pivoted in the angle of the quadrant.

69. Sinecal Quadrant. **? c. 1450–1500.**

Bronze. Radius 9 inches. St. John's College.

Marked 'T N' [by previous owner ?] and 'Pointer'.

Bequeathed in 1754 to St. John's College by John Pointer whose name, faintly scratched, was revealed under the corroded surface after two hours' rubbing with 'Brasso' by the author.

The quadrant is made of two plates of brass fastened together with small rivets at $\frac{3}{4}$-inch intervals all round the edges. One sight is missing.

The *Face* is engraved with 60 lines ruled parallel to each of the two sides, and about $7\frac{1}{2}$ to the inch. The lines are numbered along the sides in fives and the intersections of the numbered lines are emphasized by holes. The sides on either side of the *brachiolus* are graduated thus

Brachiolus

60 —— 5	0	5 —— 60
1 —— 60	0	60 —— 5

The Limb of the quadrant is inscribed with four arcs

180	10 | 170	.....	80 | 100	90
Virgo 6	Aries 1	.....		Gemini 3
Pisces 0	Libra 7	.....		Sagitarius 9
360	190 | 350	.....	260 | 280	270

The *Back* contains a rotatable brass plate, $7\frac{1}{5}$ inches in diameter, adjustable within a graduated circle of the

12 Signs, and closely engraved with fifteen graduated circles, which are traversed by a broad revolving index.

From without inwards the circles are engraved as follows :—

On Circles.	*On Index*			
Ann(?) 16 32 48 64 ... 800 [816]	an	mo⁹	aug° ♄	stel
1 2 3 4 5 10 15 100	acces	♄	recesse	
1 2 3 29	an	me⁹	mo⁹	♅
1 2 3 ..... 18 [19]	an	me⁹	mo⁹	♆
1 2 3 ... 11 [12]	an	me⁹	mo⁹	♃
Ianuarius 31 ..... December 31	an	me⁹	mo⁹	♃
Ianuarius 31 ..... December 31	an	me⁹	mo⁹ ☉	♀ ☿
Ianuarius 31 ..... December 31	an	me^{m}	ar^{m}	♂ ☽
Ianuarius 31 ..... December 31	an	me^{m}	ar^{m}	♃
Ianuarius 31 ..... 10 ber	an	me^{m}	ar^{m}	♃
Ianuarius 31 ..... 10 ber	an	me^{m}	ar^{m}	♀
2 4 6 8 ..... [to] 115	die	me^{m}	ar^{m}	☿
1 2 3 4 27	die	me⁹	mo⁹	☾
1 2 3 4 20	die	me^{m}	ar^{m}	☾
1 2 3 4 ..... 14 [15]	die	me^{m}	cent^{m}	☾

The outer circle *motus augium et stellarum* gives the precession; the second *accessus et recessus*, the trepidation; the 3rd–7th circles give the *medius motus* of Saturn, Lunar node, Jupiter, Mars, and Sun-Mercury-Venus, the 8th–12th the *medium argumentum* for the year for Saturn, Jupiter, Mars, Venus, and Mercury; the 13th–15th, the medius motus, medium argumentum, and medium centrum for the Moon.

Quadrants of the Sixteenth and Seventeenth Centuries

In 1508 Waldseemüller gave out the treatise on the quadrant of John of Montpellier as his own work, and with a change of the place-names, Paris and Montpellier, to Argentina (Tannery). In 1532 Apian produced his *Quadrans astronomicus*, and in 1527 Orontius Finaeus (1494–1555) designed a *Quadrans astrolabicus* for use in all parts of Europe; of this a second printed account appeared in 1534. The latter inventor appears to have been so troubled by imitators that he begged his friend, Louis Lassere, to defend him from them: *a virulentis malevolorum vindicare latratibus.*

Makers of Quadrants became numerous in the sixteenth century. Examples of the work of the Italians Mini Pittus of Florence, 1553, F. de Vectioli, 1577, and of Ant. Maginus, 1546–1618, are in the Evans collection.

NO. 69. T. N.'S SINECAL QUADRANT WITH PLANETARY SCALES (ON BACK)

St. John's College

New Quadrant of Profacius.
Quadrant of Equal and Unequal Hours. } 1537.

These two quadrants are included in the composite Pendent Sundial bequeathed by J. Pointer to St. John's College, and described on p. 135.

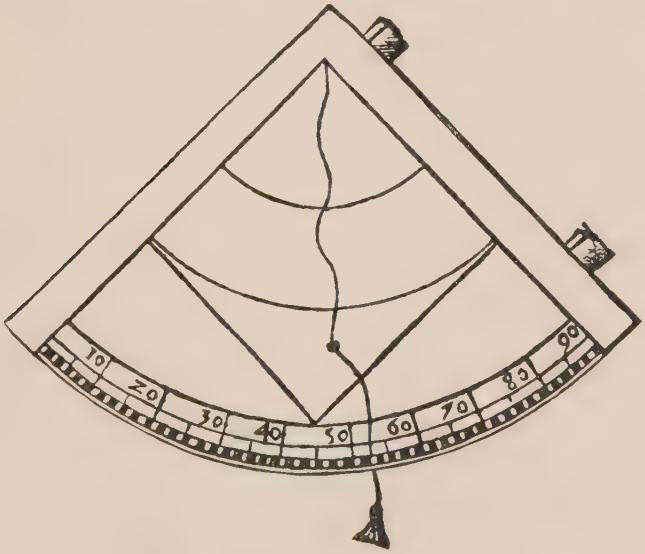
70. Quadrantal Scale. Dated 1552.

Bodleian. MS. Savile 100, f. 2.

Mention must here be made of the instrument-book known as MS. Savile 100, the origin of which I have not succeeded in tracing, in the cover of which there is a recess for the reception of a quadrant (now missing). On folio 2 is a drawing of a quadrant, the face of which is engraved with concentric parallels of latitude from 0 to 70 degrees, which are traversed by 30 special lines, of slightly sigmoid curve, of which 16 reach the 'segmentum aequatoris' along the limb at equal distances apart, while the others end in the lateral scale.

The other side of the quadrant is bordered with scales of 'Miliaria German'; and of [Miliaria] 'Italica Ptolom'; corresponding to 12 degrees, subdivided into minutes.

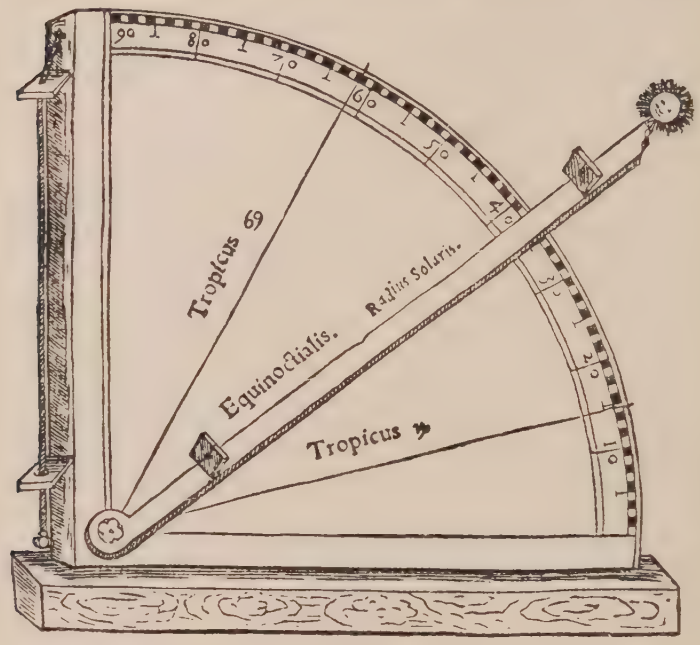
The Hand Quadrant of Robert Recorde. 1556.



RECORDE'S HAND QUADRANT, 1556.

Figured in *The Castle of Knowledge*, p. 68.

The Standing Quadrant of Robert Recorde. 1556.



RECORDE'S STANDING QUADRANT, 1556.

Recorde's Quadrant was an exact repetition of the 'Instrumentum monteregiensis', figured in the 1528 edition of the *Almagest*, p. 8v.

Three years after the publication of this quadrant an East Anglian, William Cuningham of Corpus Christi College, Cambridge, published a similar figure of a quadrant in his *Cosmographical Glasse*, 1559.

JOHN PELL, *b.* 1610, *d.* 1685, incorporated at Oxford 1631. His papers on the Quadrant, 1630, and on Sundials, remain unpublished.

Potter's Quadrant. c. 1649.

FRANCIS POTTER of Trinity College gave John Aubrey a quadrant in copper, and made him another in silver, of his own projection, which serves for all latitudes,[1] and

[1] Aubrey, *Lives*.

which he had himself graduated with beam compasses of his own contrivance. *See* vol. i, p. 116. Richard Bloxam's silver quadrant, dated 1651, is in the British Museum.

Stirrup's Universall Quadrat. 1655.

Delineavit Antonius Thompson.

A square instrument with a sinecal instrument engraved on the front and with a rotatable planisphere on the back. Thomas Stirrup, *Description and use of the Universall Quadrat.* London, 1655.

71. Quadrant. 1658.

Paper on wood. Radius 11 inches. Orrery Coll. (37).

'Henricus Sutton Londini fecit.'

Such quadrants are found dated 1656–69.

Sinecal Quadrant. 1659.

L. Evans Coll.

'Henry Sutton Londini fecit 1659.'

A sight-rule in angle of quadrant. Sinecal quadrant inscribed 'Radii' 'Circuli Altitudo Solis' 'Sinus Gradus Notati pro Azimutho'.

On back:

'Elevatio Poli Oxonii 51° 46′.'
'*Pro Hora Nocturna*'

The hour of the night is found from the ten stars

'*Fomah*	*Ala Peg*	*Cap Ari*	*Oc Tau*	*Can Ma*
Cor Leo	*Cau Leo*	*Arctu*	*Cor Sco*	*Aquila*'.

72. Quadrant. 1669.

Brass. Radius $4\frac{3}{8}$ inches. Orrery Coll. (41).

'Hen: Sutton fecit.'

This quadrant is fully described with an engraving of one dated 1658, but otherwise similar, by John Collins, 'Accountant Philomath', in his *Sector on a Quadrant of great use to Seamen and Practitioners in the Mathematiques*, 1658.

The Sutton, or Collins, Quadrant differs from the Gunter Quadrant in having altitude-circles (almucantars) inscribed on the plate; but the method of working by sliding bead and plummet and the results obtained are much the same in both descriptions of quadrant.

'Mr. Sutton's Quadrants, made above one hundred years ago, are the finest divided Instruments in the World; and the Regularity and Exactness of the vast Number of Circles drawn upon them is highly delightful to behold.' Stone, 1758.

They were sold either in the form of engraved brass instruments or as prints on paper which the observer could cut out and mount on wood or brass quadrant plates.[1] If similar prints were obtainable at the present day an inexpensive and highly educational instrument would be brought within the reach of school children.

Books, too, were not unfrequently illustrated with copperplate engravings of quadrants, which unscrupulous persons used to cut out and mount for use as instruments. In the Christ Church Library there is a case in point. In a copy of M. Dary, *Dary's Diarie or the Description and Use of a Quadrant*, 1649, there was such an illustration. There is also a marginal note by a former owner of the book:

'I have Taken away ye Quadrant or rather I should say ye whole Figure which heere was inserted; and Pasted it on a Boarde.' G.F.

It was a Sutton's Quadrant.

73. Gunter's Quadrant. 1665.

Ashmolean Museum.

Radius $3\frac{1}{2}$ inches. Brass: with lateral sights.

Inscribed 'I. W. 1665.' (John Worgan) No. 45 A. 1892.

Constructed for about latitude 51° 40′. On the face is a quadrant with divisions numbered 1–10–1 including a table calendar LY = (leap years) (16)60 to (16)84. D(ominical) L(etters) and Ep(acts).

On the back a rotating plate is engraved with the circum-polar constellations *Vrsa Mi*, *Vrsa Mai*, *Auri*, *Per*, *Cassi*, *Ceph*, *Dra*, with an altitude scale of 47° to 90°. The border of the plate is divided into days and months indicated by their initial letters, and can be adjusted within a scale of hours 1–12, 1–12 engraved on the base plate.

[1] This idea was not new. L. Digges in the middle of the preceding century wrote:

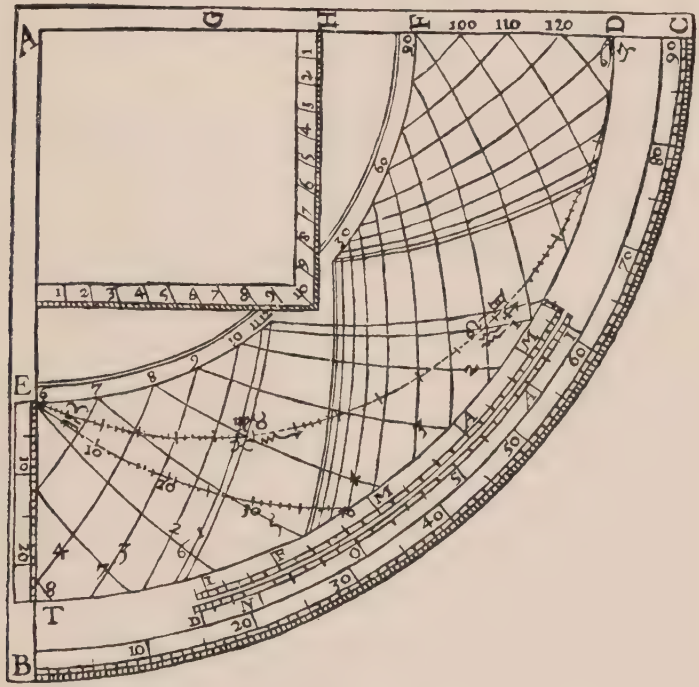
'If ye lyst not to make a Quadrante, ye may use this very wel: adding a plumbnet and lyne, with sightes or otherwise.' *Prognostication*, fol. 2, rev. of the 1564 edition. By 'this' he was referring to a printed woodcut in his book.

NO. 74. GUNTER'S QUADRANT ON STAND

Orrery collection at Christ Church

Hooke's Quadrant. 1666.

A Screw-divided Quadrant was presented to the Royal Society in 1666 by Robert Hooke, who also invented a **Reflecting Quadrant.**



QUADRANT, 1624, DESIGNED BY EDMUND GUNTER OF CHRIST CHURCH.

74. Gunter's Quadrant. 1690.

Ivory. Radius $4\frac{1}{4}$ inches. Orrery Coll.

'I. Rowley fecit.'

On stand, with three levelling screws, double sights, pin-hole, and cross thread. On the face is engraved a quadrant with divisions numbered 1–50–1; a scale of months; scale of 90°; and a projection of a part of the heavens marked with 5 stars, *Ala Pegasi*, *Oculus*, *Cor leonis*, *Arcturus*, and *Aquila*, by the altitude of which the hour of the night may be found.

The graduations along the sides of the quadrate are

marked 10–50 instead of 1–10 as in the figure in Gunter's *Sector*, 1624, p. 188.

AN

EXPLANATION

OF

Mr GUNTER'S Quadrant,

As it is enlarged with an

ANALEMMA.

BY

RICHARD HOLLAND, Mathemat.

This Book, with all Mathematical Instruments, are Made and Sold by

JOHN PRUJEAN.

Mathematick-Instrument-maker, near *New Colledge*, in Oxon.

BIBLIOTHECA BODLEIANA

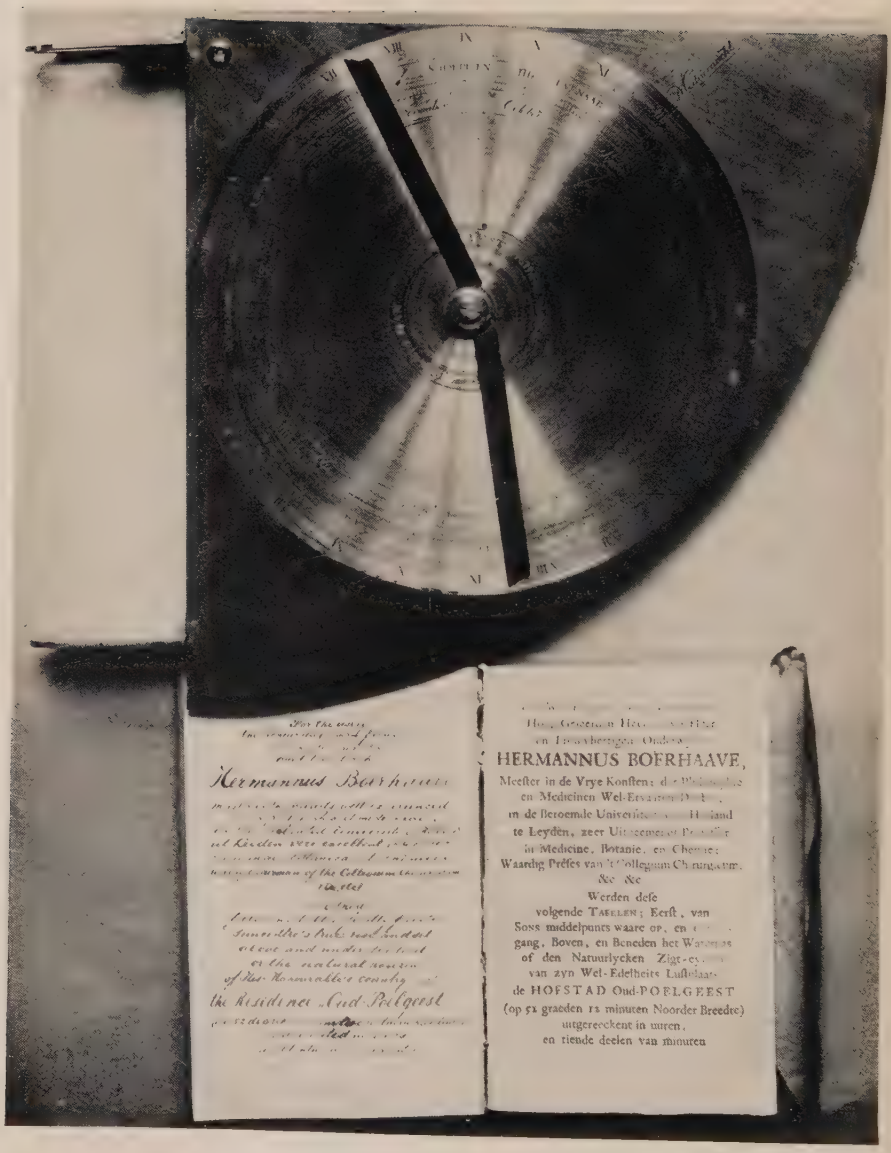
OXFORD.

Printed by *LEON. LICHFIELD* Printer to the Vniversity, *Anno Dom.* 1676.

75. Gunter's Quadrant. **18th cent.**

Boxwood. Radius $3\frac{3}{4}$ inches. Gunther Coll.

Similar to the last. The ends of the arc of Months are decorated with three fleurs-de-lys.



NO. 76. KLEMAN'S QUADRANT MADE FOR HERMAN BOERHAAVE

This plate of the Quadrant of Herman Boerhaave and Sir William Osler has been contributed by Lady Osler

76. 10-inch Quadrant with Sights. c. 1728.

The property of the late Sir William Osler.

'J. M. Kleman Fecit Amsterdam.'

Sights with slits-with-threads and pin-holes.

Hour circle marked I–XII, I–XII. Zodiac circle. Month circle. Two revolving hands or indices. 'Middach Middenacht.'

A small printed booklet shows that this instrument and tables were specially intended for the use of Herman Boerhaave at his country house at Oud-Poelgeest, at 52° 12′ N. latitude. The book was printed at Leyden in 1728 and the tables were prepared by the famous Nic. Cruquius. There is great appropriateness in this instrument having fallen into the hands of the one man who was best qualified to value Boerhaave's work.

A similar instrument has been figured by Lansberg in 1663.

Sinical Quadrant. 1739.

Perfected according to the English method of Projection.

By Jonathan Sisson.

Adams' Sinical Quadrant. 1780.

Made by *Rich*[d]. *Rust ye Corner of St. Catherines Stairs LONDON.*

Invented by John Adams (late of Waltham-Abbey), at the Academy in Brook-Street, Ratcliff.; and described in his *The Description and Use of a new much-improved Sinical Quadrant*, 1781.

This instrument was provided with a radial arm, the 'Distance Line', divided into 300 equal parts; a 'Latitude Line' similarly divided; and a 'Departure Line' on a sliding Tee-square. The 90 degrees of the arc are divided into 96 equal parts and bisected according to Mr. Bird's method. On the face is engraved a Mariner's Compass.

77. Quadrant adapted for use as a Sun-clock. Recent.

From La Siljan, Dalecarlia. Pitt-Rivers Museum.

Figured on plate facing p. 167.

ASTROLABES

Chaucer, *On the Astrolabe*, 1391, 'A Treatise full noble and of great prise.' Ludgate.

IPPARCHUS of Bithynia is said to have been the inventor of the astrolabe, but there is no evidence that he used so complex an instrument, although he would have readily comprehended the working of its several parts. The Armilla was the instrument which the Alexandrine Greeks chiefly used.

The astrolabe can hardly have been known before the time of Hipparchus, since astronomy was not sufficiently developed to require such an instrument. One of its objects, for instance, was to determine the longitude of the moon relative to the sun in different parts of her orbit; but the earlier astronomers made no such observations, since they were unacquainted with any theory of the moon's motion, and had no motive for observing her except in eclipses.

The instrument was also used to determine roughly the difference of the right ascensions and longitudes of two stars. Such observations would have been of no value unless it had been possible to ascertain also the exact place of either of the stars with respect to the equinox, which nobody did between Ptolemy and Tycho. This could not be effected without the use of tables (at least, according to any methods known in ancient times), and such tables were not within the reach of the earlier astronomers of the Alexandrian School. Tannery considers that the invention of the planispheric astrolabe is to be attributed to Apollonius of Perga (*c.* 240 B.C.)

The name 'astrolabium' is applied to an instrument described and figured by Ptolemy in the first chapter of Book V of the Almagest, *De constructione instrumenti quod astrolabium vocatur.* But this was an armillary ring with a diametric rule with sights (see p. 13). Such an armilla, as was used by Hipparchus for his observations, may well have served as the foundation of the complex instrument to which the name astrolabe is commonly restricted. The astrolabe combines the

armilla of Hipparchus and the theodolite of Theon with a projection of the zodiac and starry hemisphere and includes several other instruments as well. But we do not know for certain who were the inventors or rather composers who joined together the several parts, transforming the armilla into a 'mathematical jewel'. A Greek instrument is described in the writings of John Philopon of Alexandria of the sixth century which seems to have reached a state of perfection equalling that of the astrolabe of the Arabians.

But ancient knowledge from another and perhaps even stronger source appears to have flowed independently into the construction of our instrument. Learned Arabs[1] went to the East to study and observe, and through them the civilized nations of the West derived more of oriental wisdom than they wot of.

The synthesis of the several parts of the astrolabe would appear to have been effected by the sages of the East, but whether in India, in Persia, or in Arabia is uncertain. Of Babylonian origin, and after 539 B.C., was the subdivision of the course of the sun into the 12 zodiacal constellations, each of which is subdivided into 30 degrees. The Golden Age of Babylon has been placed in the Seleucid Period (after the advent of Greeks in the Euphrates valley), and according to Cumont and Bell Babylonian astronomy began to spread to centres of Greek and Roman culture about the middle of the fourth century B.C.

Various widely different pieces of apparatus have been known by the terms ἀστρολάβον, astrolabium, or astrolabe. Thus the word has been used to designate:

1. Spherical astrolabes with concentric movable spheres, now chiefly used as educational models for illustrating the planetary system.
2. Armillary spheres.
3. Planispheric astrolabes.
4. The Mariner's Astrolabe.
5. The 'mathematical jewel' of Blagrave (1594).

But in our account of the instrument we shall follow

[1] Compare the Arabian mathematician Albiruni's scientific tour in India *c.* 1030, described by Reinaud, *Fragments arabes relatifs à l'Inde*, pp. 135-60; and translated by Sachau.

Chaucer's example and restrict the term to its third meaning, to the flat or planispheric astrolabe and its modifications, of which the **saphea** was an early type.

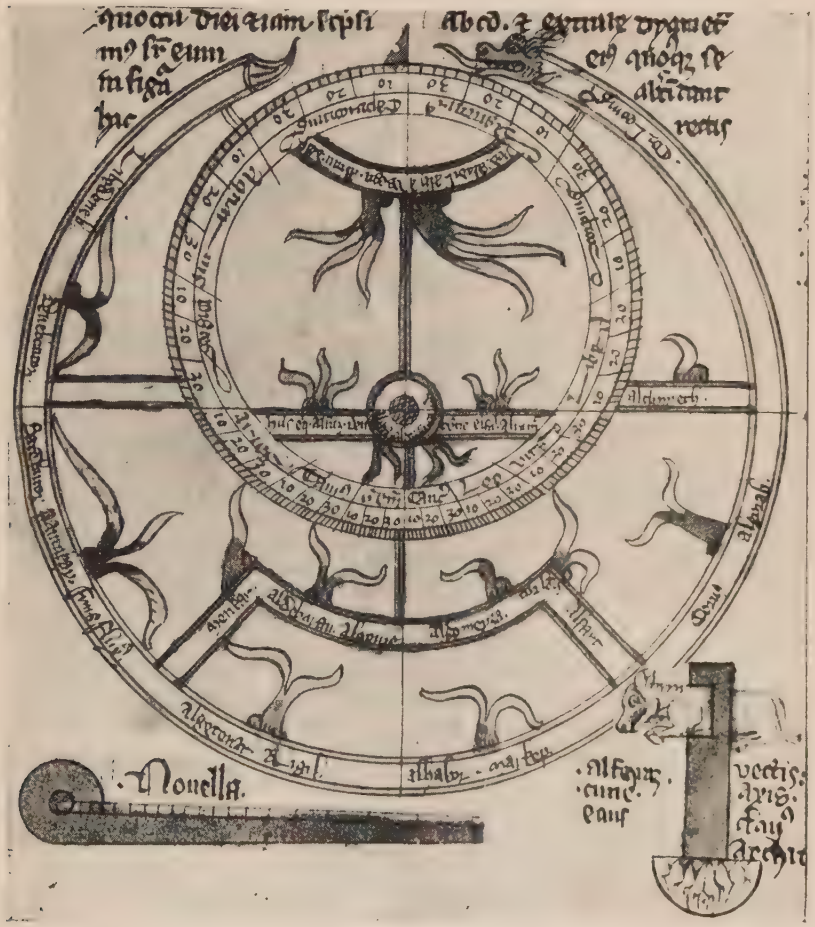
The essential parts of a Planispheric Astrolabe are the Mother, a flat heavy circular plate of metal, furnished with a shackle and ring whereby it may hang in a vertical position from the thumb of the observer. On the face, the border or projecting rim, divided into degrees and also into 24 hours, encircles a shallow space called the 'moder' or 'womb', in which are placed a varying number of movable plates or tablets, and the rete.

The Rete or Ankabut, net or spider, is a flat piece of pierced metal designed as a plane projection of the heavens within the tropic of Capricorn, the circle of the ecliptic being conspicuous in the upper part, as an inner rim. Upon this inner rim are marked the months and days and signs of the zodiac. The positions of some of the principal stars both above and below the zodiac are indicated by pointers. The number of the stars inserted upon the rete varies with the size of the instrument. In the Cambridge University Library is an *MS. Tabula stellarum fixarum que ponuntur in Astrolabio, scripta ad civitatem parisiū cuius latitudo est 48 gradus et 50 minuta. In anno domini nostri jesu christi 1223.*

The Tablets, or plates, of which there are usually several suited for different latitudes, are engraved (in stereographic projection on the plane of the Equator) with the meridian or N.-S. line, the line of intersection of the equinoctial with the plane of the horizon or E.-W. line (*Horizon rectus*), the tropics of Capricorn (close to the outer edge) and Cancer, the equinoctial, circles parallel to the horizon, called almucantars or parallels of altitude, azimuths or arcs of vertical circles which all pass through the zenith and are necessarily cut by the almucantars; the first of each of these groups passes through the points in which the equinoctial cuts the Horizon Rectus (E.-W. line); the first almucantar is the *Horizon Obliquus*, the true or astronomical horizon which separates the upper from the lower hemisphere, so that all above it is visible at the place for which the table is constructed, and all below is hidden.

In the largest Merton astrolabe, almucantars are traced for every degree.

The Rule or Izada or Alidade at the back is a metal bar furnished with sights at the ends. In certain



RETE, LABEL AND PIN AND WEDGE OF MESSAHALA'S ASTROLABE. *MS. Tanner* 192, *f.* 83, *similar to Ashm.* 1522, *f.* 87ᵛ.

instruments the sight-holes are double, the smaller for sun in daytime, the larger for stars by night.

The Label with a fiducial edge, a bar on the front face, appears to have been added in Europe.

Rete, rule, and label revolve on a central pin, which, passing through the centre of the mother and the tables, keeps them all together and represents the position of the polar axis of the earth. The pin was anciently fixed by a wedge, which from its conventional shape was known as the horse. In modern and recently repaired instruments a nut and screw often take the place of the horse.

The flat back of the mother is generally engraved with several circles and scales which vary in different instruments and will be described more in detail below. In most there is an outer circle of degrees and inner concentric circles for signs of the zodiac, months and days; while on a central space is a scale, somewhat like a protractor, of which the length is twice the width. The vertical edges and each half of the horizontal edge are divided into 12 equal parts. The two former are called umbra versa and the latter umbra recta.

Method of use. The instrument being suspended from the thumb of the observer by the ring, altitudes are observed by means of the rule or alidade; with the aid of the circle of degrees, the rete and tablets, various astronomical results can be obtained.

To find the time of day by observation of the sun.

Let the astrolabe hang freely from the thumb through the suspension ring, turn the alidade until the sun shines through the pinholes of the sight vanes and read off its altitude. Then, knowing the degree of the zodiac in which the sun is on the day of observation, move the rete round until the sun's position in the zodiac comes over the appropriate altitude circle (or almucantar) on the tablet. Set the rule to pass through the sun's position, and read where it crosses the rim by the hour lines.

'To knowe every tyme of the night by the sterres fixe,' CHAUCER, for the benefit of 'litell Lowys' in Oxford, would have proceeded as follows:

Among an heep of sterris fixe, it lyked me for to take the altitude of the feire white sterre that is cleped Alhabor; and fond hir sitting on the west side of the lyne of midday, 18 degrees of heighte taken by my rewle on the bak-syde. So sette I the centre of this Alhabor up-on 18 degrees among myn almikanteras, up-on the west syde; bycause that she was founden on the west syde. So leide I my label over the

degree of the sonne that was descended under the west orisonte, and rikened alle the lettres capitals fro the lyne of midday un-to the point of my label in the bordure; and fond that it was passed 8 of the clokke the space of 2 degrees.

And by the aid of the umbra versa or umbra recta the height of terrestrial objects can be determined, as evidently the reading of the former will indicate the height in inches of the object for each foot of horizontal distance, or if umbra recta be used the reading will indicate the height in feet for each inch of horizontal distance.

As a Universal Instrument the astrolabe had limitations both in place and time, and therein each instrument bears the evidence of the exact locality and epoch for which it was constructed. The stereographic projections of the sphere engraved on the tablets are only suited for use in the latitudes of particular places, whose names and degrees are engraved thereon. Consequently the use of an instrument might be restricted for taking observations at places within the range of the places or latitudes for which appropriate tablets were supplied.

The epoch of construction is accurately indicated by the day of the month of the vernal equinox, when the sun enters the first point of Aries. In 1923 it entered at 3.29 p.m. on March 21st. Chaucer, in his *Treatise on the Astrolabe*, addressed to his son Lowys, and dated 1391, makes the sun enter Aries on the 12th of March. In the following table the dates of the vernal equinoxes as marked on several instruments are given.

1067	Arabian Astrolabe (L. E.)	14 March
1224	,, ,,	14 ,,
1221	,, ,,	13½ ,,
1227	Mesopotamian ,,	13 ,,
	Selden Arabian Astrolabe	10½ ,,
1280 or 1340	Sloane in British Museum	14 ,,
1342	Mayer ,, ,,	13 ,,
c. 1340	Oriel	12 ,,
c. 1350	Merton	11½ ,,
c. 1390	Merton	12 ,,
1500	Stöffler	10½ ,,
1527	Hartman	10½ ,,
1571	Arsenius	,, ,,
c. 1675	Prujean	10 ,,

The sun enters Aries one day later after every lapse of 130 years.

An astrolabe in a complete form was at once a Universal Instrument and a Calculator. It was principally employed for taking observations of the sun, moon, and stars; for measuring heights of buildings, trees, and mountains, and distances generally; for ascertaining latitudes, for the determination of time; for the construction of horoscopes; and for other astrological operations.

Oriental Astrolabes

The early use of the astrolabe among the Persians and Arabs has been discussed by W. H. Morley. In some localities the instruments were made in large numbers and were widely used. In the city of Cambulac alone there were 5,000 astrologers and soothsayers who were reported by Marco Polo to have a kind of astrolabe, on which were inscribed the planetary signs, the hours, and critical points of the whole year. And in some places even the barbers had them; witness the story of the tailor of the Arabian Nights,[1] who described in detail the manner in which his loquacious barber took an observation with it.

A high standard in the knowledge of practical astronomy was preserved by means of the astrolabe among those favoured peoples who dwelt under the enduring clearness of the Chaldean sky. I, myself, have seen one in use in the old Persian town of Maragha, quite near the spot where Hulagu, the grandson of the great conqueror Genghis Khan, founded an astronomical observatory and equipped it with modern instruments of large size. A degenerate type of astrolabe, still to be purchased in the bazaars, serves the pious Mussulman as a means of observation for determining the hours of prayer and the direction of Mecca.

The modern instruments are in general between four and six inches in diameter, and are held up by a loop of cord passed through the ring during an observation.

Although Arabian astronomers made great use of

[1] Lane's 1889 edition, p. 332.

ASTROLABE OF AHMAD AND MAHMUD, A. D. 984

Lewis Evans collection

astrolabes, they do not seem to have effected any essential improvement in the method of observation. Their instruments were in general larger and better constructed than the armillary rings of the Greeks, and greater precautions appear to have been observed to ensure the accuracy of results, especially by the improvement of instruments for angular observation.

What is remarkable is the almost simultaneous diffusion by the Arabs of the mathematical and natural sciences in countries so widely apart as Bagdad and Cordova. It is owing to this extended distribution that so much of the early learning of the Greeks and Indians has escaped destruction.

As there are two fine oriental astrolabes in the Oxford collections, it is of interest to note what the great biographer, Ibn Abi Jakub an-Nadim, had to say, about A.D. 987, concerning the history of the instrument and its makers. Moreover, we have at present on exhibition in Oxford the earliest dated astrolabe known, dated A.H. 374 or A.D. 984, the 'Astrolabe of Ahmad and Mahmud, the sons of Ibrahim the Astrolabist of Ispahan'.[1]

Treatise on the (astronomical) Instruments and their Makers

Translated from the *Kitab al-Fihrist* (= Book of the Record) of Ibn Abi Jakub an-Nadim (*c.* A.D. 987). Suter, *Zeit. Math. Phys.*, xxxvii, Suppl. 1892.

There were Astrolabes in early times (even Planispheres), and the first man to make them was Ptolemy; but it was also reported that even before him instruments of this kind had been made, but this cannot be affirmed with certainty: the first maker of a flat astrolabe [in modern times] was called Apion (?) the Patriarch. These instruments were [at first only] made in the town Harrân, later their manufacture was more widely extended and better understood; however, they increased in number and work, for craftsmen extended [first largely] under the dominion of the Abbasides from the days of Al Mamun until our own time; for when Al Mamun

[1] This instrument, together with the rest of his unrivalled collection, Mr. Lewis Evans has offered to the University of Oxford.

undertook to support observing, he applied to Ibn Chalaf al-Marwarudi and he constructed the Armillary Sphere for him, and it is still in the possession of a learned man of our country; Marwarudi had also constructed Astrolabes at an earlier date.

The Names of the Instrument Makers

Ibn Chalaf al-Marwarudi; al Fazari.
Ali ben Isa (al-Asturlabi), servant or apprentice of al-Marwarudi.
Chafif, pupil of Ali ben Isa, a clever and excellent man.
Ahmed ben Chalaf, pupil of Ali ben Isa.
Muhammed ben Chalaf, pupil of Ali ben Isa.
Ahmed ben Ishak al-Harrani.
ar-Rabi ben Farras al-Harrani.
Katastulus (?), pupil of Chafif.
Ali ben Ahmed, the geometer, pupil of Chafif.
Muhammed ben Schaddad al-Baladi.
Ali ben Surad al-Harrani.
Schudscha ben . . ., pupil of Batulus (?).
Ibn Salam, pupil of Batulus.
al-Adschla, maker of Astrolabes, pupil of Batulus.
al-Adschlajja, his daughter, also a pupil of Batulus.

The pupils of Ahmed and Muhammed, the sons of Chalaf.

Dschabir ben Sinan al-Harrani.
Dschabir ben Kurra al-Harrani.
Sinan ben Dschabir al-Harrani.
Farras ben al-Hasan al-Harrani.
Abu'r Rabi Hamid ben Ali, pupil of Ali ben Ahmed, the geometer.

The pupils of Hamid ben Ali.

Ibn Nadschijja, his name was . . .
al-Buki, his name was al-Husain, but was also called Abdassamad.

To the preceding [eminent?] makers of instruments belong—

Ali ben Jakub ar-Rassas.
Ali ben Said, the Euclidian.
Ahmed ben Ali ben Isa of recent times.

TABLE OF DATED ASTROLABES BY EARLY MAKERS

Those marked L.E. are at present in Oxford.

Date.	*Name of Maker.*	*Place.*	*Owner.*
	PERSIAN		
undated	AHMED-IBN-KHALAF *c.* 950		Bibl. nat. Paris.
undated	HAMED-IBN-ALI *c.* 964		Palermo.
984	AHMAD AND MAHMUD, sons of Ibrahim the Astrolabist	Isfahan	L. Evans.
1223–4	MOHAMMAD IBN ABI BEKR IBN MOHAMMAD AL RASHIDI	Isfahan	,,
1227–8	ABD AL-KARIM AL-MISRI AL-USTURLABI	Syriac	,,
1235	ABD AL-KARIM AL-MISRI AL-USTURLABI	Damascus	Brit. Mus.
1288	SHEMS AL DIN MOHAMMED SAFAR	? Mosul	L.E.
1400–50	MEHDI of Yazd	Yazd	,,
1647	MUHAMMAD SHAFI, astronomer of Janabad; MUHAMMAD of Yazd	Yazd	L.E.
1651	IBRAHIM ? IBN SHARAF UD-DIN HUSAIN	Meshed	,,
	MOORISH		
1029	MOHAMMED IBN AL SAAL	Toledo	Berlin R. Library.
1066–7	IBRAHIM IBN SAID	,,	Madrid Mus.
1067–8	IBRAHIM IBN SAID ASSOHLI	,,	L.E.
1197	IBRAHIM IBN SAID	Valenza	Mus. Kircher, Rome.
1208	ABOO BEKR IBN YOUSEFF	Morocco	Desc. by Sarrus.
1212	MOHAMMAD IBN FOUTOUH AL-KHEMAIRI	Seville	M. H. Sauvaire.
1221	MOHAMMAD IBN FOUTOUH AL-KHEMAIRI	,,	L.E.
1224	MOHAMMAD IBN FOUTOUH AL-KHEMAIRI	,,	,,
c. 1400	ABDULLAH IBN SASI	African	,,
1494	MUHAMMAD IBN AHMAD AL-BATUTI	Arabian	,,
	INDIAN		
1644	MOHAMMAD IBN ISA IBN AL-HADDAD	Lahore	L.E.
	EGYPTIAN		
1282–3	AHMAD IBN ALI	Cairo	L.E.

Manuscript Authorities

Of the several treatises on the Astrolabe that have come down to us from the Arabians, one of the earliest and most important is that of the astronomer Messahala, *c.* A.D. 780. His work was known through Latin translations, and four of his works were afterwards made still more widely known by being printed at Nuremberg in 1549.

Of manuscripts of Messahala's *Compositio et Operatio Astrolabie*, the Cambridge University Library possesses four, of which Ii. 3. 3, dated 1276, is the best. The second part, beginning 'Nomina instrumentorum sunt hec', is reprinted in full in Skeat's edition of Chaucer's *Astrolabe.* The first part, beginning 'Scito quod astrolabium sit nomen Graecum', deals with the method of constructing the instrument, and is illustrated with excellent drawings of an astrolabe 5 in. in diameter.

In the Bodleian both MS. Canonici 61, *Opus Astrolabii secundum Mescallath*, and MS. Ashmole 1522, ff. 80–95[a] (temp. Edw. II), *Prohemium in Astrolabium Messehalach*, are illustrated with good diagrams. The stars marked upon the rete of the latter, shown on p. 185, are:

Libedeneb.
Denebkaitos.
Batenkaitos.
P menkar.

Finis flux.	Menkar.	hu[9]. eq.		Yed.
Alg.	Aldebar.	Alfazade.		Aladil.
Rigil.	Alg.	Algo.		Alhaue.
Alhabre.	Algomeiza.	all.		Vega.
Nackor.	Cor loīs.	Bene.	Ursa.	Almirach.
Corvus.	Alfart.	Elfa.	Taurus.	
Algenab.	Alchimech.	Alra[g].		
Cor Scorpii.				

Among other Arabian descriptions of the astrolabe may be mentioned—

Ali ben Isa, *Treatise on the Astrolabe and its use.* *c.* 700. Brit. Mus. MS.

Baha al-Din Muhammad al Amili, *Treatise on the Astrolabe*, which he called a 'Safhah' or 'plate' because the whole of it may be written on a plate of the astrolabe. Brit. Mus. MS.

Shams al-Din Muhammad ben Ahmad ben 'Abd al Rahim al-Mizzi, *b.* before 1291, *d.* 1349. Studied in Cairo: settled in Damascus, where he invented several ingenious and highly valued astronomical instruments.

Ali (Abu al Hasan) Al Marrakushi (of Morocco), *Treatise on astronomical instruments of the Arabs.* Translated into French by J. Sédillot. (With plates.) 1834.

For notices and illustrations of early oriental astrolabes, see the following:

W. H. Morley, *Description of a Planispheric Astrolabe, constructed for Shan Sultan Husain Safawi, King of Persia.* 1856. *c.* 1700.

Article 'Astrolabe' in the *Penny Cyclopaedia.*

L. Sédillot, *Mémoires sur les instruments astronomiques des Arabes.* Paris, 1841.

F. Sarrus. Figured an Astrolabe of 1208 in *Mém. Soc. Mus. hist. nat. Strasbourg,* 1853. Figured in Repsold.

Almerico da Schio, *Di due Astrolabi in caratteri cufici occidentali.* With 6 plates. Venice, 1880.

Lewis Evans, *Some European and Oriental Astrolabes,* 'Archaeological Journal', 1911.

G. R. Kaye, *The Astronomical Observatories of Jai Singh.* Calcutta, 1918.

G. R. Kaye, *Astronomical Instruments in the Delhi Museum.* 1920.

The Oxford Instruments

Three instruments in the Oxford collections represent the astrolabe in its eastern form. Two of them have a special interest for their personal associations; the one with Archbishop Laud, the other with John Selden, the latter having been the first to point out the source of Chaucer's thorough knowledge of the astrolabe. These oriental instruments indicate the type from which the western and English astrolabes were copied and evolved. Indeed, the earlier western instruments differ from their Arabian prototypes in little save the lettering being in western instead of Arabic script. A comparison of the fine astrolabe of 1208, described by Sarrus, with the Laudian instrument, with one of the Merton instruments, and with others in the unrivalled collection of Mr. Lewis Evans, shows how little the construction of the instrument has changed in the course of years.

It was from the East that the astrolabe received the decorative quality which it never lost; even after being

reproduced for centuries by European craftsmen. It has always been the most artistic of common scientific instruments.

78. Arabian Astrolabe. **Type of 1224.**

Bodleian Library, MS. Arch. Seld. A. 72 (1).

Diameter $7\frac{3}{4}$ inches.

With eight tablets; one made for the latitude of Morocco.

This beautifully finished instrument came to the University with the Library of John Selden in 1659.

Suspension is by a ring of round metal connected with the bracket by a swivel and shackle. A grummet for a cord with an eyesplice has also been attached to the ring.

In front the raised rim of the mother is constructed of a ring of cast brass brazed on to the thin disk that forms the back of the instrument. It is graduated into 360 degrees, numbered in groups of five. The inside of the mother has been left plain. Of the 8 tablets, 6 are engraved for various altitudes, but have no lettering; one is lettered on both sides; and one is engraved with a projection of the celestial sphere, with latitudes and longitudes traversed by the ecliptic which cuts the peripheral circle of 360° at 23° 50′ from the poles. The other side of this tablet is engraved with the double or bipolar series of almucantars and azimuths so usual in oriental, though rare in European astrolabes.

The tablets are marked for the following latitudes:

0°		and 15°	[Sana is on lat. 15°]
22° 50′		„ 25°	[Mecca is on lat. 21°]
28°		„ 32°	
30°	[Cairo]	„ 34°	
31° 30′	[Morocco]	„ 33°	
37°	[Granada]	„ 45°	
40°		„ 48°	[Paris is on lat. 49°]

With the exception of the third and seventh tablets which have almucantars for every 6th degree ('sudsi'), the almucantars are drawn and numbered for every 3rd degree: the astrolabe is therefore 'thulthi' or tripartite.

The fifth tablet is inscribed 'li-'ardh Marākish', for the latitude of Morocco 31° 30′. The range of tablets is suitable for use between the latitude of Paris and the Equator.

The finely designed r e t e is provided with pointers for 29

NO. 78. SELDEN'S ARABIAN ASTROLABE (FACE)

NO. 78. SELDEN'S ARABIAN ASTROLABE (BACK)

named stars, 15 being within and 14 outside the zodiac circle. A list of the stars is given in the table on p. 222. The zodiac circle is attached to the outer rim by the middle bar and by very slender straps. Its bevelled edge is divided into 120 divisions, 10 to each sign. In design the star-pointers closely resemble those of an instrument made at Seville in A.D. 1224 and now in the collection of Mr. Lewis Evans.[1] In both instruments 29 stars are marked upon the rete.

The rete is provided with 4 knobs for moving it, as was not infrequent among instruments of the Moorish type. The first point of Aries corresponds to the 10¼ of March.

The *back* is engraved with a border of seven concentric circles surrounding four quadrants containing (1) an instrumentum horarum with the hours numbered in Arabic 1–6 on the outer side, and 7–12 nearer the middle; (2) a quadrant divided into squares, for the sake of clearness every fifth line being dotted (cf. some modern squared papers); such a quadrant was used as a graphical table of sines. It was called the Quadrant of the *destûr* by the Arabs. It is crossed by 30 horizontal lines (*mabsût*) and by 30 vertical (*menkûs*). When used by itself such a quadrant was usually fitted with a thread, with a moving bead, fixed to the centre of the quadrant, but in our instrument, its place would be taken by the revolving alidade. (3) and (4) scales of 'al-ḏal al-ka'im' or umbra recta and 'al-ḏal al mabsūt' or umbra versa, each divided into 12 parts and numbered 3 6 9 12, 12 9 6 3.

The lettering is in the style known as Western Cufic, or *magrebin*, which remained in use for such inscriptions for many years after it had been superseded by the *neschi* script for ordinary purposes.

In order from without inwards the circles are:

1. Circle of numbers of degrees numbered in fives from 0 on the horizon to the pole at the point of suspension: 5. 10. 5. 20. 5. 30., &c., to 90.
2. Circle of 360 degrees.
3. Numbers of degrees in each sign of the Zodiac: 5. 10. 5. 20. 5. 30.
4. Names of 12 signs of the Zodiac.
5. Circle of days of the months.
6. Numbers of days in each month.
7. Names of the months. An interesting feature is that these names are in Latin transliterated into Arabic characters. The first point of Aries in circle 3 corresponds to 10½ March in circle 5.

[1] L. Evans, *Arch. Journal*, 1911, lxvi, No. 27.

79. Arabian Astrolabe. Writing of c. 1400.
Diameter $6\frac{3}{8}$ inches. Bodleian Library.

Presented in 1636 by Archbishop Laud, whose arms, impaling Canterbury, are engraved on the back of the bracket. It is believed to have been given to Laud by John Selden, who gave the Library a second astrolabe in 1659.

An instrument of fair design but of imperfect execution. The divisions of the scales are unequal, the ornaments unfinished, the tablet circles rudely scratched and the lettering with a rough burr that shows both the lack of finish and that the instrument has never seen much service. Were it modern, one would say that it was of cheap manufacture made to be sold in a bazaar to tourists. It is a rough copy of a good class of instrument: it is also quite perfect.

Suspension is by ring and shackle, pivoted to a large bracket. In section the ring is square, so that the instrument, like a modern balance, must hang on a knife-edge.

The mother is all cast in one piece, and has been turned out in a lathe. The front has a rim $\frac{3}{8}$ in. wide, divided into 360 divisions numbered by fives. On the inside of the 'womb', as the sunken centre is called by Chaucer, are engraved six concentric circles of names of 50 eastern towns, with their several longitudes and latitudes, 31 in the outer circles, 19 in the inner circles.

The changeable tablets are 5 in number. They are notched for engaging with a stop on the inside of the rim, and are so kept from revolving with the rete. Almucantars are drawn one for every 6th degree (*sudsi*), so that there are only 15 of them: they are numbered on most of the plates. The tablets are engraved on both sides: some are double ended. The inscribed tablets are for latitudes 22° and 27°, 26°, and for 28° and 40°.

The rete, furnished with a single brass knob, is inscribed with the names of 28? stars, 15 within and 13 outside the Zodiac. The list is given in the table on p. 222.

The alidade or 'rewle', carrying a pair of pin-hole sights, rather out of alinement, is roughly graduated with two scales. One, a scale of declination, starts from the centre and is numbered 5. 10. 5. 20. 5. 30., &c., to 60 in a length of $2\frac{7}{8}$ in.; the divisions on the other half are numbered from the end to the middle, 1 to 6 and back again to the same end, 7 to 12, along the fiducial edge of the rewle.

NO. 79. LAUD'S ARABIAN ASTROLABE (FACE)

NO. 79. LAUD'S ARABIAN ASTROLABE (BACK)

The Back.

The back is divided into four quadrants, the rim of the two upper quadrants is divided into degrees, numbered in groups of six from the horizontal 6, 12, 18, &c., up to 90 at the zenith. The left upper quadrant is divided into squares by cross-lines $\frac{1}{12}$ in. apart; the right upper quadrant is divided by 15 radii and arcs of concentric circles.

The rim of the two lower quadrants is divided into 30 divisions only, by lines drawn at every third degree, and numbered as in the upper hemisphere, 6, 12, 18, &c., downwards to 90 at the nadir. The left lower quadrant is ruled with vertical parallel lines (about $8\frac{1}{2}$ to the inch); the right lower quadrant contains, as is usual, the scales of umbra recta and umbra versa, inscribed in Arabic 'lines equal' and 'lines reversed'. The 12 divisions of the scales are all numbered: this is never the case in the corresponding scales on European instruments.

Proceeding from left to right the towns enumerated are:

On the outer circles.

The Towns.	Longitude.	Latitude.
Cairo	68° 20′	30° 20′
Aden	76 41	11 41
City of the Apostle. Peace be upon him (Medina)	75 20	25 41
Mecca	74 10	21 40
Taif	74 30	21 20
(Temple) Jerusalem	66 30	31 50
Damascus	70 41 ?	38 25
Aleppo	72 10	35 50
Nakh	81 55	38 40
Tabriz	82 41	38 41
Bardaa. Barder on equator	88 41	40 30
Bulgar	? 95 41	49 30
Kufa	79 30	31 30
Maaden	72 41	38 10
Bagdad	80 41	38 34
Basrah	84 41	30 41
Firozabad	84 30	28 10
Schiraz	88 41	29 36
Jeyd	89 41	22 40
Hamadan	88 41	25 10
Sava	85 41	25 41

On the inner circles.

The Towns.	Longitude.	Latitude.
Balkh	101° 41′	36° 41′
Badhassan	104 34	34 10
Negara[1]	94 30	35 50
Samarkand	99 56	39 34
Khojend	105 35	41 55
Cashgar	106 30	44 41
Khotan	104 41	42 41
? Hormuz	92 41	24 41
Cabul	104 40	35 41
Cashmir	108 41	35 41
Tibet	110 41	40 41
Kandahar	104 40	38 41
Mooltan	104 35	29 40
Lahore	109 20	31 50
Delhi	108 35	28 41
Agra	115 41	24 8
Achnadabad	108 40	28 55
? Serandib	104 41	10 41
Kanbait ? Khanahibad	109 20	22 20

[1] ? Nagar N. of Srinagar = Cashmir.

On the outer circles (*continued*).

The Towns.	Longitude.		Latitude.	
Kaswin	85	41	36	41
Ispahan	86	40	52	25
Kashan	86	41	34	41
Kum	85	40	34	45
? Rai	86	20	35	41
Astrabad	89	25	36	50
Sawer	91	30	36	5
Nizapur. Nishapoor	92	30	36	21
Tus[1]	92	30	34	41
Herat	94	20	34	30

Note. The frequent occurrence of the number '41' may indicate that the engraver, when in doubt as to the exact number, cut '41'.

80. Indian Astrolabe. Dated **Sambat 1730 = A.D. 1673.**

Diameter $4\frac{1}{2}$ inches. Pitt-Rivers Museum.

Inscribed in Prakrit characters 'Jos'i Indraji-Kasya Yantram'.

(= Diagram of the astronomer Indraji.)

A pretty little instrument with a large bracket for suspension decorated with lightly chased foliated ornament on the face and inscribed on the back. Centre pin lost.

The face has a rim $\frac{2}{10}$ in. wide with degrees numbered in groups of 6. Inside the womb are engraved in six concentric circles the names of 20 eastern towns not readily decipherable with their latitudes and longitudes, 4 spaces being left blank.

My friend Mr. Gambier-Parry has read the names as follows:

Outer circle: Vadāvar 21·22, 114·55; Delhi 28·0, 113·0; Lahore 31·50, 108·20; Mulattā (? = Mooltan) 30·40, —; Ajame (= Ajmeer) 26·0, 111·9; Amadā (= Armadabar) 23·0, 108·90; Pambhāi 22·0, 108·0; Murāt (= Surat) 21·30, 110·0; P . . . . . 28·11, 113·9; Kurute 30·10, 112·0; Sy ābre 33·0, 106·0; Sechar (= Sukkur); Nag . . tri; . . . la 20·0, 111·0; Ahmadabad 12·0, 115·0; Gotaku 18· , 115·10; Bijapur 19·10, 114·40; Yara . . . 21·20, 112·0; Ujjaya (= Ujain) 23·30, 110·50; Gavāler (? = Gwalior) 25·22, 114·0; Āgarā (Agra) . . . 115·0; Kaśī (= Benares) 26·15, 117·20; . . .; Apo . . .

Inner circle: Ahmad; . . .; Vijāpur; . . .; Ujaya; Gavaler; Kasi; . . . .

[1] In Khorassan.

There are 4 tablets engraved for latitudes, 'aksham', for

18° and 26°
20° and 23°
24° and 27°
29° and 32°.

A tablet of the horizons (*al-Ṣafīḥat al-āfāqiyah*) is also included. The horizons are arranged in four groups with 8 in each, and by each group are two scales giving the total obliquity (northern or southern).

The rete is inscribed with the abbreviated names of 23 stars, 8 within and 15 outside the zodiac circle.

The back is divided into 4 quadrants. As in the Laudian Arabian instrument the left upper quadrant (1) is a 'quadrant of the *destūr*' of sines, but the right upper quadrant (2) is engraved as an instrumentum horarum. The left lower quadrant (3) is inscribed 'Paramakrantī' (= Highest). The right lower quadrant (4) contains scales of umbra recta and versa with the customary 12 divisions.

The acquisition of the Evans collection would raise the number of Oriental Astrolabes in Oxford from 3 to 33. Of these the most important are the oldest dated instrument known of A. D. 984, the astrolabes made for Abool Fehih Moosa, son of King Aboo-Bekr (1227-8), and for Shah Abbas II (1642); a Mesopotamian instrument with a geared calendar-movement in it; a very early Moorish example dated A. H. 460 or A. D. 1067; and an Egyptian variety, perhaps the only one of its kind known.

The Astrolabe in the West

The Arabian conquerors no doubt found their way to Spain by use of the astrolabe, and introduced it into the west, but it does not appear to have come into general use among western peoples until the beginning of the fourteenth century.

We should like to think that an astrolabe, or at least a description of one, had found its way to the centre of Anglo-Saxon culture in Northumbria and was thus known to Bede, the reputed author of a treatise on the instrument. The treatise, however, contains Arabic names, and is almost certainly a much later work, a Latin translation from an Arabian author, perhaps by Joannes

Hispalensis, that has been included in editions of Bede's collected works.

There is no ground for believing that Bede could have known Arabic, even if any Arabian could have composed so explicit an account of the instrument at that early age, a full century before the brilliant epoch of Al Mamun.

Among the few who are said to have realized the value of the Arabian learning before A.D. 1000 was GERBERT, afterwards Pope Sylvester II (950–1003),[1] but like many a man more learned than his neighbours, it only brought him the reputation of being in league with the devil. The noble inheritance of the Arabs was not rendered generally accessible to European students before the publication of Latin versions of their books. We can hardly overrate the debt which later learning owes to the otherwise obscure scholars who performed so valuable a service, but their names will live with those of the works they translated. No doubt the greater part of the pioneer work was done by Joannes Hispalensis in the twelfth century and by Gerard of Cremona, who are the best known of these transmitters. To the former translator we owe the first Latin treatise on the astrolabe. A clearly written manuscript of his, *De Astrolabio Componendo et de regulis ejusdem*, with small but neat diagrams of all parts of the instrument is in the Bodleian.[2] Another early account is contained in a treatise by Hermannus Contractus,[3] of which, in MS. Digby 174, we have John of London's copy of the twelfth century. It is not illustrated with figures, but is beautifully written.

THE SAPHEA

The **Saphea,**[4] also known as the Universal Astrolabe or Astrolabe of Arzachel, has been made known by the re-publication by Sédillot (pp. 185–8) of half of a small

[1] A list of Gerbert's astronomical apparatus is given in Richerus, *Histor.* iii. 43 (*Monumenta German. Script.* iii. 617).

[2] MS. Canonici 340, Spanish, sixteenth century. Cf. especially the figure on f. 53.

[3] Contractus *Liber de mensura astrolabii* has been published by Pez and is reproduced in Migne's *Patrologie latine.*

[4] Safiha = Lat. saphea = Disk = Tabula.

Latin treatise by WILLIAM ANGLICUS entitled *Compositio tabulae quae Saphea dicitur sive astrolabium Arzachelis*,[1] and dated 1231.

The treatise is of interest because it is the work of a western savant, who has mastered, not without difficulty as he naïvely acknowledges, the principle of the construction of this Arabian instrument.

The Saphea of Arzachel is a portable circular disk, held vertically by an armilla and furnished with an alidade pivoted at the centre and, when horizontal, touching the zero graduation-mark of a border divided in degrees. The lower quarter of the circle, turned towards the observer, is marked with the same lines as the quadrant *sans curseur*, with this difference, that the hour lines are concave towards the vertical instead of being, as in the Quadrant of Robertus Anglicus, concave towards the line of sight. Scales of umbra recta and versa may also be added in the right lower quadrant. The alidade, on which a point can be marked, also serves for determining the hour on the Saphea, quite like the string and bead on the Quadrant.

Tannery supposes that Arzachel, to avoid the addition of a sliding index to the alidade, marked the back of the Saphea with a series of concentric arcs with radii proportional to the sines of the heights.

LIST OF STARS MARKED ON ARZACHEL'S SAPHEA, 1231 (WILLIAM ANGLICUS)

Aries.		Cor Leonis	= Regulus.
Caput Mulieris	= α Androm.	Cauda Leonis	= α Leonis.
Cor Piscis	= β ,,	Coll Corvi	= ε Corvi.
Caput gorgonis	= Algol.	Abramec	= Arcturus.
Cor Tauri	= α Tauri.	Cor Scorpii	= Antares.
Pes Orionis	= β Orionis.	Cauda Scorpii	= λ Scorp. ?
Humerus eius sinist.	= γ Orionis.	Sagitta Sagittarii	= γ Sagit. ?
		Vultur cadens	= Vega.
Alhabor	= Sirius.	,, volans	= Altair.
Algomeiza	= Procyon.	Cauda Gallinae	= α Cygni.
Coll Leonis	= γ Leonis.	Humerus Equi	= β Pegasi.

There is no old example of a Saphea in Oxford.

[1] This was added to a translation of Arzachel *de Saphea* made by Profacius and Ioannes Brixiensis in 1263. Steinschneider has tried to identify Guillelmus Anglicus with an astrologer-physician who wrote *De urina non visa*, and with probable good cause, for in

Chaucer's Astrolabe

The first and the best description of a planispheric astrolabe in the English language was written by Geoffrey Chaucer. Nor was the theme unworthy of our great astronomer-poet, for during the period of the great oceanic discoveries the astrolabe, next to his compass, became the navigator's greatest assistant. Astrolabes figured prominently in the frontispieces of works on seamanship; Vasco da Gama, Drake, and Columbus navigated by them; and by their help the position of new-found lands could be approximately settled.

Chaucer had no dreams of the great work that the future would lay upon his instrument. His chief concern was that there was no simple account of it in plain English. He had sent his young son, 'litell Lowys', up to Oxford at the tender age of ten under the tutorship of the 'nobilissimi philosophi Magistri' N. Strode. The childish fancy of Lewis had evidently been struck by the mystery and attractive appearance of some astrolabe, and he had asked his father if he might learn about it. The father being pleased with the child's 'abilite to lerne sciencez touchinge noumbres and proporciouns', i.e. arithmetic, sent him a small astrolabe, 'a smal instrument portatif aboute' by way of combining instruction with reward. The instrument was what the Arabians termed a *nisfi*, being engraved with 45 circles of latitude for alternate degrees, instead of with the whole 90 that find room on the largest and best instruments; or, in Chaucerian language, 'the almikanteras in thyn Astrolabie been compouned by two and two'.

MS. lat. 16652, a thirteenth-century MS., the author describes himself as a citizen of Marseilles, a physician and an astronomer.

The whole passage reads as follows:

Et novit Deus quod ego Guillermus Anglicus, civis Massiliensis, professione medicus ex merito scientie astronomus dictus, ex debili principio studio vehementi et ymaginatione perspicua circa hoc opus fere per sex annos quantum licuit animam meam fatigavi; quod hoc meum principium non fuit, nisi quod Arzachel speram super meridianum, ut dictum est superius, compressit. Expletum est hoc opus anno Domini 1231 secunda die Ianuari. Et ego (precor) inspectorem huius mei tractatus et etiam aliorum meorum tractatuum, ut illos dirigat et adornet et Deus qui cuncta novit actus nostros dirigat et vere speculantes multiplicet.

Explicit Astrolabium Vniversale. Deo gratias.

This, however, was a 'suffisaunt' astrolabe for the purpose. The father, moreover, believed the Latin treatises to be too hard for his son's use and the conclusions in them not to be always reliable. He, therefore, proposed to select some of the more important conclusions, and to turn them into English with such amplifications as would render them easier for a child to understand. Chaucer makes no pretence to originality. 'I am but a compilatour of the labour of olde Astrologiens, and have it translated in myn English only for thy doctrine; and with this swerd shal I sleen envye.' The result was a treatise which after five hundred years is still the standard work on the subject in our language.

Chaucer tells us that there were in existence writings in Arabic, Greek, Hebrew, and Latin, that the Latin folk translated them 'furst out of othre diverse langages', and that his own version was based on the Latin. The particular author was recognized by John Selden, who, being himself the owner of an Arabian astrolabe now in the Bodleian Library, very naturally took interest in the matter, and thus indicated the exact course by which one branch of oriental learning had flowed into western channels. In 1619 he wrote 'I dare swear that (Chaucer's Treatise of the Astrolabe) was chiefly learned out of Messahala'.

The industry of Professor Skeat has ratified Selden's assurance by comparing the *Compositio et Operatio Astrolabii* of Messahala with the *Treatise* of Chaucer, and by thus establishing the fact that it was from the second part or *Operatio Astrolabii* that Chaucer drew almost the whole of Part I of his Treatise and about two-thirds of Part II. Of the sections which were still left unidentified by Professor Skeat I have been fortunate enough to recognize a similarity between one, section 38, *To finde the lyne merydional*, and the passage already mentioned, *Ad meridiem inveniendum*, which has been ascribed to the Venerable Bede. (See p. 26.)

The third part of Chaucer's text-book for his son has not come down to us as such, but as Professor Skeat has pointed out, there is no reason why it should, for it probably consisted entirely of tables which would have been copied 'after the kalendres of the reverent clerkes, frere I. Somer and frere N. Lenne' (= Nicholas of

Lynn). Tables of this kind would have got out of date after a few years, and scribes copying the Treatise on the Astrolabe would not have wasted time on tables which had been superseded and were of less value than the current calendar for the year.

Professor Skeat suggests that the tables selected by Chaucer for his son would have probably included:

1. Tables of latitudes and longitudes of the stars which were represented on the Rete of the Astrolabe. Specimens of such tables are found in many MSS. The one figured is taken from the Bodleian MS. Canonici 340.

2. Tables of declinations of the sun, according to the day of the year.

3. Tables of longitudes of cities and towns. Cf. MS. Canonici 340, f. 56^{v}.

4. Tables for setting clocks and finding the meridian altitudes of the sun.

Such collections of tables occur in many astronomical MSS., e. g. MS. Camb. Hh. 6. 8; MS. St. John's, Camb. F. 25, &c., &c.

MANUSCRIPT AUTHORITIES

The principal manuscript of Chaucer's *Treatise on the Astrolabe*, 1391, is the one in the Cambridge University Library, MS. Dd. 3. 53, illustrated with a great number of neatly drawn figures, which has been taken by Skeat as the basis for his edition. The Bodleian MS. E Museo 54 is an uncorrected copy of it: and the diagrams are rough. Both were probably written in London about 1400.

Of the other Bodleian manuscripts—

S. C. 2142 is illustrated with figures and contains a table dated 1403. This volume belonged to J. Chaunteler of Oxford early in the sixteenth century. *c.* 1400

MS. Rawl. 9 contains 6 well-executed diagrams. *c.* 1420

MS. Ashm. 391. The fine illustrations have been greatly injured by damp. The 24 divisions on the rim of the face of the astrolabe are marked with Lombardic letters A–Z. xvth cent.

S. C. 2151
(12822) MS. Rawl. Misc. 3 } do not contain figures.

MS. Rawl. D. 913 contains good figures.

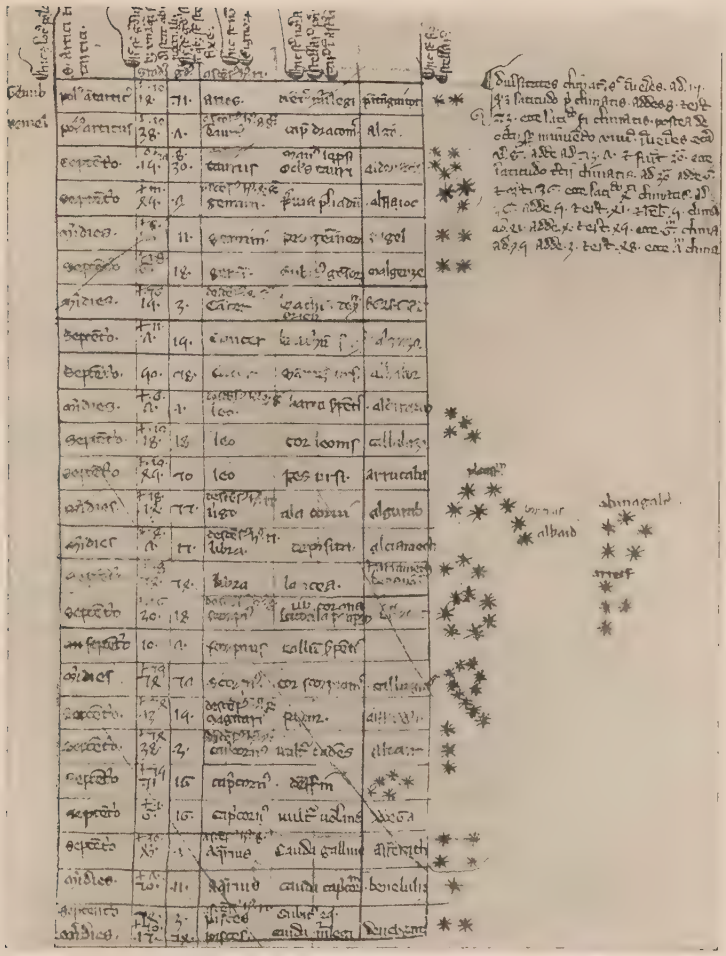


TABLE OF ASTROLABE STARS, xiv cent.
MS. Canonici Misc. 340, *f.* 54.

WESTERN ASTROLABES IN OXFORD COLLECTIONS

81. Astrolabe and Quadrant. **c. 1340, before 1350.**

Diameter $13\frac{4}{10}$ inches. Oriel College.

This instrument and the 1350 Astrolabe in Merton College belong to a very rare type of which, so far as we know, there are no early English examples out of Oxford, and which may have been constructed for some member of the early School of Astronomy at Merton College. The chief peculiarity of the type consists in the absence of changeable tablets and of a raised rim round the base plate to contain tablets and rete. They are astrolabes without a mother, and they are combined with quadrants of large size.

The bracket for suspension is missing; it has evidently been torn away from the notch at the upper side of the thin disk.

Taylor, who has reported on this instrument in his *Further Remarks on an Astrolabe*, has arrived at a different, and we believe erroneous, conclusion. He considered that the plate was made to lie in a mother and was kept steady there by a tooth filling the notch which he described as 'neatly cut'. Now the notch is not neatly cut, one side is distinctly ragged, as if a piece of metal had been torn out; next, there is no sign of a central hole for the pin which would have threaded all the movable parts together in the mother. Taylor also suggests that the instrument was for calculation rather than for observation. This view is refuted by the scars for quadrant sights and by the *brachiolus* for a plummet-line at the back: both were part of an instrument for observation.

The Face.

The rim of the disk, $\frac{4}{10}$ in. in breadth, is divided into 360° and into hours marked 1–24, the zero point being defined by a cross ✢. The inner portion is engraved with a table approximately suited for the latitude of Oxford 52°. The almucantars are drawn for every third degree, thus 42, 45, 51, 54, 57, 60. The astrolabe is therefore a 'thulthi' or tripartite.

The rete is very like that of the Merton instrument. It

NO. 81. THE ORIEL ASTROLABE, C. 1340 (FACE)

NO. 82. THE MERTON ASTROLABE, C. 1350 (FACE)

bears names of 18 stars. (See table, p. 222.) Upon a peripheral ring are inscribed the names of the months

'ffebrr mart april mai^{9} Juni^{9} Juli^{9} Au^{9} 8b^{er} 9^{ber}'

from which it may be seen that the first point of Aries corresponds to $11\frac{1}{2}$ of March.

The positions of the stars on the rete were originally read on the scale on the rim by means of a revolving pointer or label, but this has been broken off short. In instruments of later date, e. g. a planisphere in the Kildare St. Museum, Dublin, and in Hartman astrolabes, this label was engraved with a declination scale. The instrument does not appear to have been provided with a rule: observations were made by the quadrant sights on the back.

The Back.

Upon the back are the following instruments:

1. A quadrant of $9\frac{6}{10}$ in. radius. The limb is divided along the circumference of the plate, thus giving the quadrant in the middle an effective increase of radius to 12 in. and allowing space on the limb for graduation to $\frac{1}{2}$ degrees.[1] The plummet-line was suspended from a small hanging brass arm or *brachiolus*, as in the case of the Merton instrument.
2. A quadrantal scale of umbra recta and umbra versa. The divisions are numbered 3. 6. 9. 12. 9. 6. 3, and the marginal notes ∂' *minor* and ∂' *maior* probably refer to them.
3. Lines of an *instrumentum horarum inaequalium* are drawn within the quadrant.

It is perhaps idle to speculate on the history of this remarkable instrument, or on how it may have come into the possession of Oriel College, but the theme has attractions. Its many points of resemblance to the Merton instrument, dated 1350, are obvious—the lettering might have been by the same engraver—and inasmuch as the differences in construction all indicate an advance in the construction of the Merton instrument, the Oriel astrolabe must be regarded as the earlier type and therefore older than 1350. In the light of College history it is a matter of suggestive interest that Oriel

[1] For an example of the use of astrolabe to travellers about 1320–50 and of the precision with which latitudes were then stated in degrees and minutes, see Sir John Mandeville's *Voiage and Travaile*, cap. 18.

should have been the other College in which this rare type of astrolabe should have been found, for there is a personal link between the two Colleges in SIMON BREDON. This scholar, noted as a physician, mathematician, and astronomer, was a Fellow of Merton about 1330. He was therefore an original member of that eminent school of astronomers of which Ashendon and Rede were the reputed founders. Bredon wrote on the eclipse of 1345 and at his death in 1372 left by will a large collection of mathematical and astronomical works to Oriel College. Was the early astrolabe which we have just described, and consider to be the prototype of the Merton instrument, a part of his bequest? We think it must have been.

82. Astrolabe, Plumb Level, and Quadrant. c. 1350.

Diameter $14\frac{1}{4}$ inches. Merton College.

Brass; engraved, 'Lat. 52. 6^m Oxonia.'

This instrument had been examined by Robert Taylor, who described it as 'the most curious instrument it has been my fortune to see', and expressed a wish that it might be reproduced by the anastatic process.

The shackle and ring for suspension are missing, and there are no changeable tablets, since the instrument was intended solely for use in the latitude of Oxford.

The point of suspension is opposite to the first point of Aries, which comes a little before the noon-point of March 12th.

A peculiar feature of the instrument are the two marginal plates, $9\frac{3}{4}$ in. apart, fixed one on either side of the suspension bracket; each carries a vertical plate, *tabula perforata*, pierced with large and small pin-hole sights. A small plumb-line was suspended from a movable bar or *brachiolus* below the foresight, so that altitudes could be measured, instead of by a centrally-pivoted alidade. In this respect the instrument resembles a quadrant.

The Rete of a very light and elegant design bears the names of 32 stars. See table, p. 222. The rule has a fiducial edge.

The Face is engraved with a border surrounding a table with azimuths and almucantars drawn for every degree (the Astrolabe is therefore 'tamm' or perfect), scales of umbra recta and versa, and an instrumentum horarum.

NO. 82. THE MERTON ASTROLABE, C 1350 (BACK)

The border has six bands. Counting from the outer edge:

1. The limb of the Quadrant, divided to $\frac{1}{2}$ degrees. The degrees are numbered by fives from 0° to 90°. The slant lines are not 'for ornament' as Taylor has suggested.
2. The divisions, numbered 3, 6, 9, 12, 12, 9, 6, 3 of scales of umbra recta and versa on the limb of the quadrant. They are mixed up with the quadrant degree-numbers, but their purpose is clearly shown by the inscriptions at the ends of the scale:

   'Circul' altinis t pūcta umbre v̄se' (= Circulus altitudinis et puncta umbre verse), and 'Puncta umbe rēe' (= Puncta umbre recte).

   In the same circle is a note:

   'H̄ō ꝗ pm⁹ 8· culou ꝯūcto4 defuit p° anno p⁹ bisextū 2⁹ : 2° · 3⁹ : 3° · + 8⁹ v. anno de ſviet bisextili.' (= Nota quod primus 4 circulorum conjunctorum deservit pro anno post bisextum. 2ᵘˢ : 2° . 3ⁱᵘˢ : 3ⁱᵒ et 4ᵗᵘˢ vero (?) anno deserviet bisextili.)
3. Circle of divisions of days of month.
4. Names of months and numbers of days in each.
5. Names of signs of Zodiac and numbers of their degrees.
6. Oblique lines joining divisions of 5 and 7. This is a very noteworthy and, so far as we know, unique feature, by means of which each degree in circle 7 is divided into thirds. It is the earliest use of transversal or diagonal lines with which we are acquainted.
7. Circle of degrees, divided into groups of five, numbered 0–360 in Arabic numbers to be read from the centre, but in the series 15, 45, 75, 105 . . . 145 are numbered as 1, 3, 5, 7, . . . 23.

Thus this border contains the essential parts of the *back* of an ordinary astrolabe.

The Back is engraved with (1) an outer Zodiac circle, comprising a circle of degrees and a circle of names of the signs and of numbers of their divisions, 10 . . . 30, within which and touching it at the first point of Cancer are (2, 3) two other circles, not concentric, each divided into 12 signs and 360°. These circles are inscribed 'Aux sol' et Venis' and four other circles lying detached within, and marked

4 Mercuri'	touching	3	at about	24 of the Scorpion
5 Jupit'	,,	4	,,	30 of the Lion
6 Marš	,,	5	,,	29 of Cancer
7 Satū	,,	5	,,	15 of Capricorn

There is also a table which seems to give the corrections to be made for precession through the century beginning with 1350:

(*Anni Christi*)		(*Motus octavae spherae*)
anni X'	mot⁹. 8ᵉ. ſpe	
1350	mᵘ	
138–	20	
1416	40	
1450	60	

Near the centre are two small circles, one of which is divided by 36 drilled holes, numbered by threes 1–12.

And round about are sundry other notes of a word or two, referring to centres described as 'ſol', 'ceᵐ drn̄tꝑ', 'ceᵐ en̄ᵘtꝑ', 'ceᵐ defꝑ', 'luᵘ' (evidently contractions for the terms *centrum equantis* and *centrum deferentis*).

These planetary circles recall the figures drawn to illustrate some of the MSS. of the *Theorica* of Campanus, a good example of which may be studied in MS. Digby 168, f. 61.

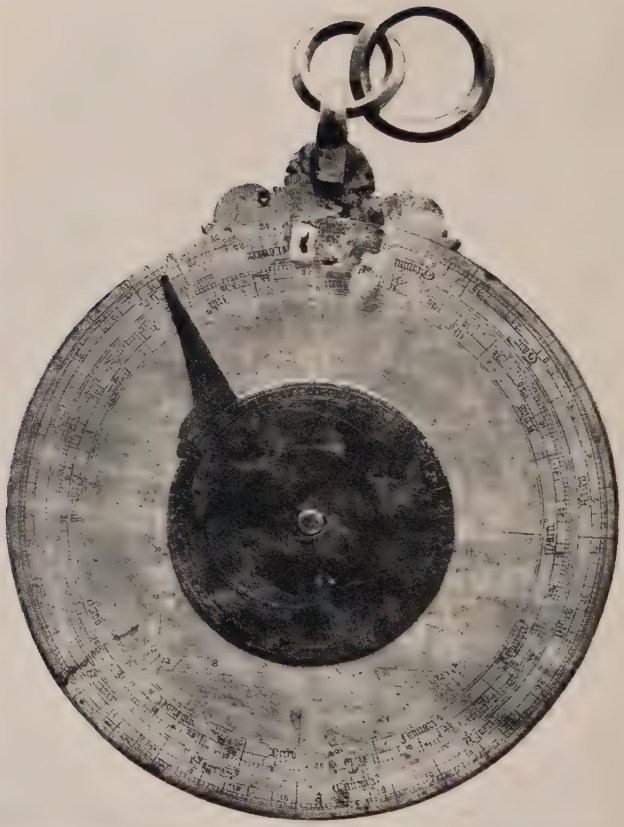
As the face bears the inscription 'Lat. 52·6ᵐ Oxonia' and as the indications of date, deduced from the first point of Aries and from the table of precession, are suitable, Taylor conjectured that the instrument was made for a Merton man in the middle of the fourteenth century; perhaps even for Ashendon or Rede, perhaps at Oxford under his own eye.

83. Astrolabe. **c. 1390.**

Diameter 9¾ inches. Merton College.

A massively built instrument, but unfortunately very imperfect owing to loss of rete and rule, and to later alterations, such as re-engraving and the addition of a lunar dial and index. A rather puzzling instrument: the characters on the back are Gothic, those on the tables being rather Lombardic; while the general

NO. 83. THE MERTON ASTROLABE, C. 1390 (FACE)



NO. 83. THE MERTON ASTROLABE, C. 1390 (BACK)

appearance and especially the bracket and suspension rings appear to be oriental.

The edge is ornamented with a shallow moulding. The bracket is 3-lobed and is attached by a shackle to two massive rings, ◇-shaped in section, for suspension, thus providing a knife-edge bearing, howsoever the rings may happen to hang.

The Face.

The rim, about $\frac{8}{10}$ in. wide and about $\frac{1}{4}$ in. in height, is slightly bevelled, giving the impression that it has been filed down to remove earlier divisions and that it has been re-engraved. It is now marked with three circles.

The outermost is the Circle of Hours I–XII, I–XII, representing the twenty-four hours of the day. The two inner circles represent degrees, from 0° to 360°.

Each of the three tablets has a tooth which fits into a recess undercut in the rim of the mother, and kept them from revolving with a 'rete' which has been lost. The horizon rectus is engraved ORIENS OCCIDENS on each table. One tablet is engraved on the mother

CLIMĀ I XVI [C. Verde]

The three removable tablets are engraved for Climates III–VII.[1]

CLIMĀ III	XXX	[Cairo]
CLIMĀ IIII	LATITVDO. XXXVI	[Gibraltar]
CLIMĀ V	LATITVDO. XLI	[Naples]
CLIMĀ VI	LATITVDO XLV	
CLIMĀ VII	LATITVDO XLVIII	[Munich]

In the place of the tablet for the 2nd Climate is one for

LĀTITVDO LONDONIE LII.

Upon the *Back* are engraved seven concentric circles, and

[1] Stöffler (*Fabr. Astrol.*, f. 10) quotes Joh. de Sacrobosco as the authority on the Seven Climates, but states that Martianus added an eighth. *Climata*, or parallels drawn through places in which the longest day is of equal length, were introduced by Hippocrates, *c.* 400 B.C. *Zones*, similar to those already drawn out for the celestial sphere, were first introduced by the Pythagoreans. Parmenides of Elea (544–430 B.C.) distinguished five zones: 1. Torrid zone between the tropics of winter and summer, uninhabitable on account of the heat; 2. and 3. two Frigid zones, uninhabitable on account of cold; 4. and 5. two intermediate Temperate zones.

the N–S and E–W cross lines. Reading from the edge inwards we note:

1. Degrees numbered in tens up to 90 in each quadrant, the zero points being at the extremities of the E–W line.
2. Circle of 360 degrees.
3. Circle of the degrees of the Zodiac, numbered 10, 20, 30 in each sign.
4. Circle of names of the 12 signs in Old English letters.
5. Circle of 365 days of the year.
6. Circle of numbers of days of month, 10, 20, 30 (or 31).
7. Circle of names of the months.

Below the centre of the circles are the scales of *umbra recta* and *umbra versa* each divided into 12 parts and numbered, but of little use in their present state because they have been partly covered over with a lunar dial—evidently a later addition to the instrument.

Lunar Dial

A dial, $4\frac{1}{2}$ in. in diameter, revolves with the pin that goes through the whole instrument. It has a large index finger projecting from the first point of the $29\frac{1}{2}$ spaces on the periphery. Each space is subdivided into quarters, but as a half space is left between 29 and the beginning of 1, the subdivisions are 118 in all. The front of the dial is marked with the heart-shaped curve used in conjunction with another over-lying plate (now missing) for indicating the phases of the moon.

The style of lettering on the back is suggestive of that of other instruments of the fourteenth century, for example, the English instrument described by Ferguson in *Archaeologia*, lii. The A's and R's are very similar and the vernal equinox is March 12, so that its date may not be very different from that of the Oriel Astrolabe No. 81. It has been suggested with some probability that one of the tablets was adapted for use in this latitude by being re-engraved with lines suited to London. The moon dial was evidently an afterthought, perhaps an addition to an instrument already imperfect by the loss of rule and rete.

The rete would most certainly have included star pointers for the three stars 'Menkar', Algeuze', and

'cor leonis', that are specially mentioned as occurring on an 'astrolabium colleg. de Merton' in MS. Bodley 619, in which are most interesting Latin notes taken from Messahala and added to Chaucer's *Astrolabe.*

84. Astrolabe. **1527.**

Bronze. Diameter $6\frac{3}{8}$ inches. St. John's College.

Inscribed on the back with the name of the maker:

GEORGIVS HARTMAN
NORENBERGE FECIT.
ANNO MD XXVII

ASTROLABE BY G. HARTMAN, 1537.
Block lent by Royal Geographical Society.

This with other mathematical instruments was given in 1634 to St. John's College by Archbishop Laud, whose arms are engraved upon the back. The bracket is artistically chased with scrolls and two roses, a design which may be seen upon other examples of Hartman's work, e. g. on his 1537 astrolabe in the British Museum and on Mr. Lewis Evans's No. 2024 which is stamped GEORGIVS HARTMAN NORENBERGE FACIEBAT ANNO MDXXXVII. Another, stamped GEORGIVS HARTMAN NORENBERGAE

FACIEBAT ANNO MDXLVIII, is in the South Kensington Museum. The adoption of 'Tudor' roses as part of the design has been suggested to indicate that these Hartman astrolabes 'were made for English use, possibly for presentation to some royal personage, or for use in the British Navy' (Ionides). But the same design is also characteristic of the contemporary work of Johannes Wagner, also of Nuremberg, and, as Mr. Lewis Evans has suggested, was probably copied from an Italian original, of which he has an example in his collection.

The shackle which is connected with the swivel and ring is also ornamented, and even the shackle-pin is kept in place by a washer designed as a 4-pointed flower.

Hartman's graduations and finish were finer and more accurate than those of the instruments of his predecessors.

The Face. The rim, soldered to the base plate, is $\frac{1}{2}$ in. wide and $\frac{1}{4}$ in. in height. It is engraved with three circles.

1. The outer circle carries both the numbers of the Hours 1–12, 1–12, and the degree numbers in fives 5, 10, 15 . . . 90 on two quadrants from the zenith to the horizontal.
2. Degree numbers 90 . . . 5 . . . [0] . . . 90. The four quadrants are numbered independently.
3. Divided to single degrees.

The Pin, Rule, and Rete are missing. They were probably very like those of the 1537 astrolabe by Hartman described and figured by Ionides.[1] The rete would have been made for 27 stars. The rete or star-map would have been traversed by a declination scale also threaded on the pin or polar axis. By setting the first point of Aries to 0 hour, the right ascension of each star could be read off by the bevelled edge of the declination scale, and by the use of the scale of declinations—called LATITUDO SEPTENTRIO and LATITUDO MERIDIO—the declination of the star could also be obtained. In a similar instrument it was found that while the positions of some stars could be found within a degree of arc of declination, and a minute of time in right ascension, generally variations up to 2° or 3° of arc, and 4 or 5 minutes of time, were met with.

[1] Description of an Astrolabe. *Geographical Journal*, October, 1904, p. 411.

NO. 84. HARTMAN ASTROLABE, 1527

St. John's College

The tablets are stamped on the LINEA AURORE[1] for the latitudes for which they were to be used. For the sake of comparison, the latitudes of the corresponding plates in the Hartman astrolabe in the British Museum are also given:

The Laudian Astrolabe		Brit. Mus. Astrolabe
LATI, XXXIX	(Lisbon)	39°
LATI, XLII	(Rome)	42°
LATI, XLV		45°
LATI, XLIX M, XXVII	(Nuremberg 49° 50′ lat. 27° longitude measured E. of Madeira)	48°
LATI, LI N		51°
LATI, LIIII	(York)	54°

The covered surfaces of the tablets are practically in new condition and still show on the projecting tongues the faintly scratched latitude numbers that helped the maker to identify his plates.

The inscription upon the middle plate may therefore be taken as convincing evidence that this instrument was made for a traveller whose centre was Nuremberg, which is distinctly against the British Navy theory propounded above.

The Back. The circles counting from the outside are—

1. Numbers of degrees grouped quadrantly from 0–90, from the horizontal to the zenith and nadir.
2. Circle of degrees for noting the position of the alidade.
3. Numbers of degrees, 30 counted in fives for each sign of the Zodiac.
4. Names of the signs of the Zodiac.
5. Divisions for the days of the months.
6. Numbers of days of the months counted in fives.
7. Names of the months.

The middle space is bisected by a horizontal line, above which is an instrumentum horarum with curved lines numbered for the 12 hours: below are scales of UMBRA RECTA and UMBRA VERSA.

The first point of Aries coincides with the 10½ of March as in Hartman's other instruments.

[1] 'Linea Aurorae vel crepusculina', see P. Apian's *Cosmographia*, p. 25. It is also explained by Stöffler, *Fabrica astrolabii*, 1535, f. 10.

85. Astrolabe. **1571.**

Diameter 13½ inches. Merton College.

Inscribed on the base of the bracket with the name of the maker, *Gualterus Arscenius nepos Gemme Frisij Louanij fecit anno 1571.*

This fine Flemish astrolabe was left to the College in 1598 by John Woodward, Fellow in 1547. Gualterus Arsenius was a noted instrument maker in Flanders, who five years previous to the date of the Merton instrument, had completed a chef-d'œuvre, a great 2-ft. astrolabe which became the property of Philip II of Spain, and is now in the Archaeological Museum at Madrid, and with which our instrument has many features in common. Arsenius' mathematical and astronomical knowledge, like that of Ferdinand Arsenius of Antwerp, was no doubt derived from his uncle Regnier (Frisius) Gemma, a Dutch physician, astronomer, and mathematician (1508–55), author of the *De principiis astronomiae et cosmographiae* and *De Astrolabo*, Antwerp, 1556.

In this country our instrument closely resembles the fine Arsenius astrolabe in Mr. Lewis Evans's collection, No. 2047 dated 1565, with 55 stars marked upon the rete.[1]

Suspension is by a ring attached to an elaborate bracket with sculptured supporters. In a shield between the supporters and below the shackle is a round box for a compass needle (now missing), an addition which may also be seen in the instrument by Ferdinand Arsenius in the South Kensington Museum.

Face. The rim of the mother, ½ in. wide and ¼ in. high, is soldered to a base formed of two plates soldered together. The rim is engraved with three circles, an hour circle, the 'horarum limbus', numbered I–XII I–XII, a circle divided into ½ degrees, and a circle of degree-numbers 0–360 starting from the VIth hour.

51 fixed stars are marked upon the beautifully designed rete, upon the back of which the stars are numbered. See table, p. 222. The tablets are lined with 90 almucantars within

[1] An astrolabe of somewhat similar type, although not marked with the maker's name, is preserved in the Library of King's College, Cambridge. Date 1540. It is provided with three tablets marked for the following latitudes:

Pro elevatione poli	39 (Lisbon)	and 41 (Naples)
	45	and 52° 30′
	48	and 51

the horizon obliquus: the astrolabe is therefore a 'tamm' or perfect astrolabe. The three tablets are marked—

PRO ELEVATIONE POLI		48 *Gra*
,,	,,	50 *Gra*
,,	,,	52 *Gra*
,,	,,	54 *Gra*
,,	,,	56 *Gra.*

thus giving a range from the latitude of Freiburg to that of Edinburgh. It is noteworthy that the latitudes chosen are less well suited for Louvain 51° or Paris 49° than for the latitudes of London, York, and Edinburgh. The instrument, unlike the great Spanish astrolabe which is provided with a tablet for 49°, or that of Ferdinand Arsenius with its tablet for 51° (Louvain), was therefore adapted for use in Britain.

One side of the third tablet is marked with 90 circles of regularly diminishing radii which intersect two points on the *Horizon rectus*[1] and surround scales of *horae inaequales* and of *horae aequales* numbered *H. antemeridiem* 1–12, and *H. postmeridiem* 1–12. In the lower semicircle are also scales of umbra recta and umbra versa numbered

$$\left\{\begin{matrix} 2, & 4, & 6, & 8, & 12 \\ 10, & 20, & 30, & 40, & 60 \end{matrix}\right\}$$

with corresponding divisions.

Inside the mother is an Italian *rosa dei venti* with the Italian names for winds and points of the compass. This compass, described as the Quadratum nauticum Gemmae Frisii in the latter's *Cosmographia*, f. 24, is inscribed within a $8\frac{1}{4}$ in. square. Starting at the top is—

MERIDIES	Auster	Mezzodi
	Longitudo minor sive Occidentalior	
		Mezzodi libeccio
	Libonotus	
	Lebeccio	Libeccio
	Africus	
		Ponente libeccio
OCCIDENS	Zephyrus	Ponente
	Longitudo maior et Borealior	
		Ponente Maestro
	Corus	
	Magistralis	Maestro
	Circius	
		Maestro tramontana

[1] The plan is engraved on f. 28 of Gemma Frisius' *Cosmographia*, 1545, under the circles of his Speculum cosmographicum.

SEPTENTRIO	Aparctias	Tramontana
	Longitudo maior aut Orientalior	
		Greco tramontana
	Aquilo	
	Greco	Greco
	Caecias	
		Greco levante
ORIENS	Subsolanus	Levante
	Latitudo minor vel Australior	
		Levante seirocco
	Vvlturnus	
	Syrocho	Seirocco
	Euroauster	
		Mezzodi seirocco

The alidade carries both pin-hole and slit sights (*rimulae* of Tycho). One half is graduated with the hours of rising and setting of the sun:

Horae	*Ortus.*	1 . . . 10
	Occasus.	12 . . . 2

Each hour is divided into quarters along the fiducial edge of the rule. The other half measures the *Declinatio meridi*[*onalis*] and the *Declinatio septent*[*rionalis*].

The Back.

The entire surface is covered with a projection of the celestial globe about 13 in. in diameter, with the apparent path of the sun, and certain of the more conspicuous fixed stars marked. North of the Zodiac are seven stars Ursa Maior, Lyra, Ophiuchi caput, Ophiuchi ma. dex. Aquila, Arcturus, Caput medusae, Hircus. South of the Zodiac are Cor♏ [Sagittarii], Postrema aqu fuse, Spica♏, Cor♌ [leonis], Oculus ♉, Canicula, Canis maior, Orionis dex hum., Orionis sini pes.

Attached to the central pin is a rotating scale divided to correspond with the divisions on the ecliptic on the planisphere. Along this zodiacal scale can be slid a perpendicular scale for measuring altitudes of stars above the ecliptic. This sliding scale can be fixed at any desired point by means of a clamping screw near a sculptured faun that ornaments the base of the sliding scale. There is a terminal adjustable pointer like the one on an instrument by Ferdinand Arsenius,[1] but the latter is 3-jointed.

[1] E 69 in the South Kensington Collection.

NO. 85. ASTROLABE BY WALTER ARSENIUS, 1571

Merton College

Signed European Astrolabes

We have noted the following signed examples of Astrolabes. Seven are in the L. Evans collection.

German

H. B. marked ♄ Δ ♄ (L.E.) 1490.
Johan Wagner Norimberg (L.E.) 1538.
Georgius Hartman Norenbergae faciebat anno 1548.
(S. Kensington Museum.)
Aegidius Cuiniet Antverpianus (L.E.) 1560.
Johannes Praetorius (Dresden Mus.) 1568.
Ioan. Antho. Lynden fac Hailbrvnnae (L.E.) *c.* 1580.
Erasmus Habermel fecit (L.E.) *c.* 1585.
[For a member of the Strozzi family.]
Tobias Volckmer (B.M.) Brunswick 1594.

Flemish

Regnerus Arsenius Nepos Gemmae Frisij fecit Louanii anno 1565.
Rennerus Arsenius nepos Gemme Frisii Louanj fecit 1569.
With plates for 39° and 42°
45° and 48°
51° and Scales of Shadows and
Horae aequales.
Rete for 33 interior and 16 exterior stars.
(Conservatoire des Arts et Métiers, Paris.)
Gualterus Arsenius Gemmae Frisi nepos Louanij fecit an. 1566.
(Madrid Museum.)
G. Arsenius 5½ in. in diam. 1567.
With 3 plates for 48° 45′ and Direction
41° and 44°
47° and Horae aequales.
Rete for 36 interior and 17 exterior stars.
(Conservatoire des Arts et Métiers, Paris.)
Gualte. Arseni Louav facieb.
(S. Kensington Museum.)
Ferd. Arssenius fecit Antverpiae :
(S. Kensington Museum.)
Ick toebehoore Philis de Din (L.E.) 1595.
Cornelius Vinch Antwerp (B.M.) 1559.
" (B.M.) 1600.

Dutch

Hooft Caius College ? 15th cent.
Sneewins, maker of the Astrolabium catholicum 1661.
(Conservatoire des Arts et Métiers, Paris.)

French

Berselius' (C. Fry) 1522.

Inscribed 'Hadriano Amerocio Berseli9 me dono dedit 1522', but the instrument has the appearance of being older, and was perhaps not made by the donor.

Rete for 13 interior and 16 exterior stars. Numerals in a peculiar script. 1st Aries = 12 March.

T. Galois 1548.
Adrianus Descroliers (B.M.) Paris 1580.
Minot (Conservatoire des Arts et Métiers, Paris.)

Italian

Vincenzo Danti dei Rinaldi (Hamburg Mus.)
Grandfather of Egnazio.
F. Egnativs Dantes (L.E.) *c.* 1580.

Portuguese

Nicol Paternal Siderograph exarabat an. 1616.
(Naval School, at Coimbra.)

Paper Astrolabes

Instances of Quadrants made by pasting paper prints of quadrants upon a suitably shaped piece of board, have already been mentioned: indeed a considerable trade in the manufacture of cheap Sutton's quadrants seems to have been carried on in the seventeenth century. So, too, observers who could not afford to purchase expensive metal astrolabes appear to have made use of instruments made of wood, cardboard, and paper usually printed from an engraved plate. There are four such paper astrolabes in the Evans collection: one by George Hartman, 1542, one by Johan Krabbe, 1583, one by Philip Danfries, 1584, and one by John Prujean. It is this last instrument that is of particular interest to us in Oxford because it was printed and put together by a forgotten local instrument maker whose place of business is believed to have been in New College Lane.

Paper Astrolabe. **c. 1670.**

L. Evans Collection.

'Johã Prujean Fecit Oxon' (*c.* 1663–92).

'Latt. S 51°–45′'.

An astrolabe of paper and cardboard on wood; 8 inches in diameter, ½ inch thick. No loose plates.

The outer limb shows a scale of hours 1 to 12 twice, divided into ¼ths; the inner shows degrees numbered each way from N. and S. to 90° at the equator.

There is an outer ring to the rete numbered from Aries to 360°. The lines of the equator and tropics are cut out in cardboard.

Lyra
Aquila
Cor Hydra
Rigel
Sirius
Procyon
Aldebaran
Capella
Betelgeuse
Sol
Luna
Spica
Antares
Regulus
Arcturus
Deneb
Altair
Vega
Polaris
Dubhe
Mizar
Alkaid
Algol
Mira
Alpheratz
Mirach
Algenib
Menkar
Rasalhague
Sadalmelik
Sadalsuud
Fomalhaut
Deneb Kaitos
Diphda
Alphard
Alkaphrah
Alkes
Alphecca
Zaurak
Rigel Kentaurus
Canopus
Achernar
Hamal
Sheratan
Menkib
Mira
Alcyone
Aldebaran
Capella
Betelgeuse
Rigel
Procyon
Sirius
Regulus
Spica
Arcturus
Antares
Vega
Deneb
Altair
Fomalhaut
Deneb Kaitos
Diphda
Alphard

Rete for 19 stars :

Small whals tail	9°	Verg. Spike	197°
Oc ♉	64°	Arct	209°
Orio gird	78°	S. Bal.	218°
gre dog	100°	N. bal.	225°
Argo Navis	129°	Cor ♏	242°
Cor Hydrae	137° 30′	Lyra	277°
Alcot	189°	Aquila	293°
Cor C	193°	fomalha	340°

This is likely to have been one of the last astrolabes to be manufactured in England: their place has been taken by the instruments devised by Ferguson and others, which preceded the modern Planisphere of which the one published by Phillips is a familiar type.

I have seen a somewhat earlier paper astrolabe of 7 inches in diameter in the Conservatoire des Arts et Métiers in Paris. It is marked *G. Picquet Faciebat* and was sold by *Chez Johan Lebrun faiseur de spheres, astrolabes et autres instruments géometriques rue St Jacques, Au Globe céleste*, 1642. It is provided with five plates for Leyden, Rome, Paris, Antwerp, and Pl. . . . (?)

THE USE OF THE ASTROLABE.
MS. Bodl. S.C. 2144.

COMPARATIVE TABLE OF

For other star lists see

Arabic names	*Laud*	*1224 L. Evans*	*Type of 1224 Selden*	*c. 1340 Oriel*	*1350 Merton*	*1390 Archaeologia*
Sadr	+			Sceder		
Betn al hut				Mirac		+
Kaff al Khadib	+	⟨Caph⟩ al Chadib	Khadib			
Zanab al qītas	+	Dzaneb Ketus	Zanab Qītus			
Batn al qītas		Matn Ketus	Matn Qītus	batonk	Batonkaitos	+
Akhir al nahr					Finis flux	
Kaff al jazmā'					Menkar	+
Ras al ghul		Ras al-Ghul	Ghul			
'Ain al ṣūr						+
'Aiyuq	+	Al Debaran	Dabaran	Ala	Al deb˘	+
		Al aiouk	'Aiyūq	⟨Alhaioth⟩	Alhaios	
Rijl al jauzā al yusra	+	Rigil	Rigil		Rigil	+
Yad al jauzā al yumna	+	Menkib al Jauza	Mankib	Elgeuze	Elgeuze	
Shi'rā al yamānī	+	Al Abour	Al 'Abūr	alhab⁻	Alhabor	+
Ras al tau'am						
Al ghumaisā		Algomeisa	Ghumaisa	algom	Algomeisa	+
Fard al shujā					Alfard	+
Qalb al asad	+	Kalb al Asad	Qalb		cor Leonis	
Zahr al dubb			Yad al-Dubb		Ursa	+
Benāt na 'sch						
Al qaid			Qāid		Benetnaz	
Qā'ida al bātīya						
Ẓahr al asad						
Zanab al asad *or* Al sarfa				Cau. le	Cau. le	+
Janāh al ghurāb			Janah al-Ghurāb	corv9	corv9	+
Simāk al a' zal	+		Al-Azal	⟨Alchimech⟩		
Simāk al rāmih	+	Al Simak al Ramih	Al-Rāmih	Al ram [ech]	Alram̊	+

STAR NAMES ON ASTROLABES

pp. 192, 201, and 205.

1513 Stöffler	*1537 Hartman*	*1565 R. Arsenius*	*Hrs. Min.*	*Modern name*		*Skeat's Numbers*
Scheder		Cassiopei	16	*Schedar*	α Cassiopeiae	49
Mirach	Andromeda	Andro: ũbi:	42	*Mirach*	β Andromedae	1
				Chaph	β Cassiopeiae	
Deneb kaytos		Cauda ceti	17		β Ceti	3
Bata kaytos	Venter ceti	Venter ceti	I 30	*Batenkaitos*	ζ Ceti	
					α Eridani	5
Menckar	Nares ceti	Nares ceti	II 42		α Ceti	6
		Medusae caput	II 43	*Algol*	β Persei	4
Algenib		Persei lat. dex.	II 53	*Algenib*	α Persei	7
Aldebaran	Oculus	Oculus ȣ	IV 11	*Aldebaran*	α Tauri	9
Alhaiot		Hircus	IV 48	*Capella*	α Aurigae	10
		Orionis sin. hum.	V 3			
		Cinguli orio. media	V 18			
Rigel algeuze	Si pes orionis	Orionis si. pes	IV 55	*Rigil*	β Orionis	11
Bed algeuze		Orionis dex. hum.	V 33	*Betelgeuse*	α Orionis	12
Alhabor	Canis maior	Canis maior	VI 27	*Sirius*	α Canis maj.	13
		Caput II anteced.	VII 7	*Castor* or *Pollux*	α or β Gemini	14
Algomeisa	Procion	Canicula	VII 16	*Procyon*	α Canis minor	15
Alphard	Hidra	Hydra clara	IX 6	*Alphard*	α Hydrae	19
Kalbeleced	Cor leonis	Cor leonis	IX 44	*Regulus*	α Leonis	20
Dubhe		Ursa major		*Dubhe*	α Ursae maj.	23
Benenatz				*Benetnasch*	η Ursae maj.	27
	Patera	Crateris fundus	X 37		α Crateris	
		Dorsum leonis	XI 51		δ Leonis	
Deneb eleced	Cauda leonis	Cauda leonis	XI 26	*Denebola*	β Leonis	24
	Corvus	Corvi ala dextra		*Algorab*	γ Corvi	25
Azimech	Spica virginis	Spica virginis	XIII 2	*Spica*	α Virginis	26
Alramech	Arctvr	Arcturus	XIII 55	*Arcturus*	α Bootae	28

Arabic names	*Laud*	*1224 L. Evans*	*Type of 1224 Selden*	*c. 1340 Oriel*	*1350 Merton*	*1390 Archaeologia*
'Unq al haiyat		Unk al Haiya	'Ung al-Haiyah			
Kafa al shimālī						
Naiyir al fakka	+	Al Phecca	Fakkah		Elfeca	+
Yad	+			Yed	Yed	
Qalb al 'aqrab	+	Kalb al Akrab	Qalb al-Aqrab	Cor	Cor	+
? Sāq						
Ras al jāšī						
? Sāq						
Ras al hawwā	+		Al-Hawwā	Alawe	alawe	
Ras al tinnīn					Taben	
Nasr al wāqi	+	⟨Al Nasr⟩ al Waki	Waq 'ī	Wega	Wega	+
Nasr al tā'ir		Altair	Al-Tair	Alth [air]	Altahir	+
Ridf		Al Ridph	Ridf	delphin	delphin	+
Sa'ad al su'ud						
Al ẓirā 'al yamīn						
Ẓanab al jadī		Dzaneb al Gjedi	Zanab al-Jadi	libed	Libed	+
Anf al faras						
Sa'ad al mulk						
Sāq Sākib al mā'					Sceach	
Mankib al faras		Menkib al Feras	Mankiḃ		Alpheraz	
Surrat al faras		⟨Al Sirak⟩ al Deyd				
Matn						

1513 Stöffler	*1537 Hartman*	*1565 R. Arsenius*	*Hrs. Min.*	*Modern name*		*Skeat's Numbers*
				Unuk	α Serpentis	
		Bootis sin. hum.	XIV 10		γ Bootae	
		Lanx boree clarior	XIV 54		β Librae	
Alpheta mumir	Corona	Corona septe	XV 17	*Alphecca*	α Cor. borealis	29
Yed	Yed	Ophiuc. sin. man.	XV 51		δ Ophiuchi	31
Calb alatrab		Cor ⟨scorpii⟩	XVI 3	*Antares*	α Scorpii	32
		Ophiuc. genu sin.	XVI 15		ζ Ophiuchi	
		Caput herculis	XVI 50		α Herculis	
		Ophiuchi genu dex.	XVII 11		η Ophiuchi	
Ras alaugue	Caputserpen	Ophiuthi caput	XVII 11	*Ras alague*	α Ophiuchi	33
		Ophiuchi ma. dex.	XVII 40			
Ras aben		Caput draconis	XVII 46	*Etanin*	γ Draconis	34
Wega	Lira	Lyra	XVIII 18	*Vega*	α Lyrae	35
Alkayr	Aquila	Aquila	XIX 26	*Altair*	α Aquilae	36
	Delphin				α Delfini	37
		Cauda cygni	XX 28	*Deneb*	α Cygni	39
		Sinister hum ⟨aq.⟩	XXI 5		β Aquarii	
Alderaimin		Cephei dex. hume	XXI 10	*Alderaimin*	α Cephei	42
Deneb algedi		Cauda ⟨capricorni⟩	XXI 16	*Deneb al Gedi*	γ Capricorni or δ Capricorni	40
		Pegasi rictus		*Enif*	ε Pegasi	
		Dexter hum ⟨aq.⟩	XXI 36		α Aquarii	
Scheat⟨aqua.⟩		Crus ⟨aq.⟩	XXII 31		δ Aquarii	45
Scheat alpheraz	Pegasus	Crus pegasi	XXII 43	*Scheat*	β Pegasi	46
		Pegasi humerus	XXII 44			
		Pegasi umbili	XXIII 49	*Alpherat*	α Andromedae	47
		Ala pegasi	XXIII 55	*Markab*	α Pegasi	

The Mariner's Astrolabe

About 1484 the astrolabe which had been 'before used only in Astronomie' was somewhat simplified and adapted for use on board ship.

John II, King of Portugal, was particularly active in securing the best instrumental aid for navigators. He 'sent men of purpose into Arabia and other countries of the East to learne further knowledge thereof' (Purchas). And he also commissioned Martin Behaim[1] to teach pilots to 'navigate by the altitudes of the sun and stars'. But according to the *Arte de navegar* by the ingenious chemist and mariner, Raymond Lully of Majorca, an astrolabium was in use among the Majorcan pilots at least as early as 1295.[2]

Columbus and Sir Francis Drake both navigated by the Mariner's Astrolabe. By its means Columbus observed meridian altitudes of the sun, from which he calculated his latitude with the tables of the sun's declination then available. And from his time on for the succeeding 250 years the astrolabe was in general use for observations at sea until 1731, when its purpose was better filled by Hadley's sextant. The method of using it is shown in all the works on navigation of the period.

Cf. frontispiece to A. Ashley's *Mariner's Mirror*, 1588. There is a good figure in William Bourne, *A Regiment for the Sea*, f. 26, 1577.

'An Astrolaby is the representation of a great Circle containing 4 Quadrants or 360 degrees.' *The Seaman's Secrets.*

No Oxford example of this simplified instrument is known to me, but so important was the part that it played during the period of the great oceanic discoveries, when with the compass it provided mariners with their principal means of determining their position, that it is greatly to be desired that a specimen may be secured for the University collections.

[1] 'Martin Bohemus by whome the Astrolabe was applied to the Art of Navigation (c. 1484) and benefit of the mariner, before used only in Astronomie.' *Purchas his Pilgrimage*, 4th edit., 1626.

[2] Humboldt, *Examen critique de l'histoire de la Géographie et des progrès de l'Astronomie nautique*, t. i, pp. 274-7. Navarrete, *Dessertacion historica sobre la parte que tuvieron los Espanoles en las guerras de Ultramar o de las Cruzadas*, 1816, p. 100.

MARINER'S ASTROLABE FROM VERA CRUZ

In the possession of R. T. Gunther

The preceding paragraph had not been long in type, before Mr. Donald Cowie was kind enough to send to Oxford for exhibition with the Evans collection, the plate of the Mariner's Astrolabe which he brought up in a Sand Pump when dredging the Harbour of Vera Cruz during Nov.–Dec. 1903. He writes that 'the harbour must have been full of much old treasure, for there were a considerable number of old wrecks, and no doubt much was dredged up only to be lost again when the hopper doors were opened out at sea and the cargo discharged'.

Mr. Donald Cowie has since transferred this astrolabe to the author in the hope that with the L. Evans collection, it may form the nucleus of a representative collection of ancient scientific instruments in the Old Ashmolean Building, which is believed to have been designed by Sir CHRISTOPHER WREN as a permanent home of the Natural Sciences in Oxford.

Mariner's Astrolabe. **16th cent.**

The property of R. T. Gunther.

Marked *A.

The base-plate only, with the suspension ring and shackle, has been preserved. It consists of a rough, massive casting of bronze, $7\frac{1}{4}$ inches in diameter, 4 lbs. $2\frac{1}{2}$ oz. in weight, so designed that the centre of gravity shall hang as low as possible. For this purpose the plate is cast thicker ($\frac{3}{4}$ inch) near the bottom than near the top, where it is only about $\frac{4}{10}$ inch thick; and, also, with larger perforations in the upper than in the lower quadrants of the instrument.

One quadrant only is divided into degrees which are numbered in both directions, 10 to 90, and 90 to 10, for measuring either altitudes or zenith-distances.

The figures are not unlike those that are stamped upon a Spanish Astrolabe dated 1558 in the Evans collection. In appearance the instrument is like the Seaman's Astrolabe of 1632, made by Nicollas Le Tellier of Honfleur, and now in the Museum of Caudebec-en-Caux, but the shackle is of a different type, and the rim of the latter instrument is graduated all round.

I am pleased to have been able to obtain this instrument, for as far as I am aware, it is the first example

of a mariner's astrolabe that has ever been shown in Oxford.

A sea astrolabe of similar type is represented with other navigational instruments in the decorative carvings over the mantelpiece in the Board Room at the Admiralty. These carvings are probably correctly attributed to Grinling Gibbons.

An unpublished description of the use of the mariner's astrolabe by THOMAS HARIOT of St. Mary's Hall is preserved in vol. vii of his MSS. in MS. Add. 6788, f. 486, in the British Museum. It is entitled *Some Remembrances of taking the altitude of the Sonne by the Astrolabe and Sea-ring.* Doubtless he learnt how to use the instrument when crossing to Virginia.

PLANISPHERES

Instruments bearing a projection of the sphere on a flat surface, used for determining the hour of day or night, must necessarily have been preceded by complete Spheres. The name of Apollonius of Perga has been mentioned as the inventor of the planisphere.

In the Oxford collections, there are planispheres on one of the tablets of the Selden Astrolabe, p. 194, and on the back of the Arsenius Astrolabe of 1571, p. 216, and we have now on exhibition a very important instrument of 1 ft. 3 in. in diameter in the L. Evans collection.

Sutton Planisphere. 1659.

L. Evans collection.

'*Henricus Sutton Londini fecit* 1659.'

Horizontal projection of the sphere on a circular brass plate 15⅜ in. in diameter, for latitude 51° 40′. Equinoxes, March 9 days 16 hrs., Sept. 12 days 12 hrs.

On the other side is an analemma constituting an astrolabe, as described in Egnatio Danti's *Dell' uso e fabrica dell' Astrolabio*, Firenze, 1578. At the bottom is a tabular calendar for 1660–1712.

Scale with twenty stars. A slotted rule revolves on the centre of the instrument: but the cursor to run in the slot, and at right angles to it, is missing.

NOTES ON THE DESIGNERS AND MAKERS OF ASTROLABES, DIALS, AND OTHER INSTRUMENTS

JOHANNES STÖFFLER, *b.* Justingen 1452, *d.* 1531.[1]

Professor of Mathematics at Tübingen, and the author of the best early illustrated description of the Planispheric Astrolabe, *Elucidatio fabricae ususque Astrolabii*, 1512–3, and also of *Calendars* and *Ephemerides*, that attained to a wide circulation during his life and were continued long after his death; indeed our Nautical Almanack is their lineal descendant. The trust that every one placed in his astronomical tables and prognostications is shown by the following story. He terrified Europe by predicting a universal deluge for 1524. His aspects of the heavens told him that in that year three planets would meet in the aqueous sign of Pisces. The prediction was believed, and President Aurial of Toulouse even went so far as to build a Noah's Ark for himself. Unluckily 1524 turned out disastrous by reason of drought!

[1] His life has been written by J. C. A. Moll in 1877, and we are glad to think that our examination of the Astrolabes in the Library at Merton College should have led to our becoming acquainted with his works on that subject there; for according to Faber's genealogical work, he was the father of Agnes, *d.* 1571, wife of Johann König, Professor of Law at Tübingen, and therefore an ancestor of our own. His published works were

1499. *Almanach nova plurimis annis venturis inservientia . . . et toti fere Europe dextro sydere impartita.* Printed by Reger, Ulm.

Later edits. in 1504, 1506, 1513, 1521 Venetiis. Ashm. 468.
Introductory pp. and years 1509–10, 14–16, 18, 26–27. Ashm. 475.
Ephemerides A.D. Incarnationis 1523–31. Auct. vii. Q. vii. 65.
Portrait on title in 1531 edit. 1532–51. Ashm. 499.
1544–56. Ashm. 493.
1532–53. Ashm. 468 (with notes).

1500. Joannes Stoffleri *Tabulae astronomicae* Tübingen: per Th. Anshelm.

1513. *Elucidatio fabricae usus Astrolabii.*

1518. *Calendarium magnum Romanum.*

1523. *Expurgatio adversus divinationem.*

1534. *In Procli Diadochi sphaeram mundi commentarius.* (Savile, x. 14.)

Among his pupils was SEBASTIAN MUNSTER, the writer on clocks and dials.

NICHOLAS KRATZER or KRATCHER.

A Bavarian, admitted to the new college of Corpus Christi in 1517. His duty was to lecture on astronomy and mathematics as Wolsey Lecturer. He was moreover 'deviser of the King's horologies' (Tunstall, 1520), and it is believed that he may have been the maker of the fine astronomical clock at Hampton Court Palace, the wrought iron frame of which is marked with the date 1540 and the letters 'N. O.' or 'N. C.' (= N. Cratzer).

While at Oxford he constructed two sundials, one for St. Mary's Church, which stood on the churchyard wall on the High Street until 1744, and another for his college garden.

His portrait, one of Holbein's finest works, is in the Louvre. Kratzer is represented standing surrounded by his mathematical instruments and holding a polyhedral dial in his hand. See p. 103.

His *De Horologiis*, now in C. C. C. Library, contains a statement that many of the directions for dialling were taken from a MS. in the Carthusian Monastery at Auerbach near Vienna.

PETER APIAN, BIENEWITZ or BENNEWITZ,[1] *fl.* 1527, *d.* 1552.

An inventor of astronomical instruments well known for his *Instrumentum primi mobilis*, dedicated to Bishop Christoph of Augsburg. His Arithmetic was published in 1532. His Quadrant and Nocturnal are mentioned on pp. 174 and 273. His son Philip Apian was born in 1531.

GEORG HARTMANN, *b.* Egoldsheim 9 Feb., 1489, *d.* 1564.

A mathematician who pursued studies both in theology and mathematics at Cologne about 1510. He travelled in Italy and visited Rome and other towns, becoming acquainted with the leading mathematicians of his day. In 1518 he returned to Germany, settled in Nuremberg, and acquired a reputation as

[1] Siegm. Gunther, *Peter Apian*, Prag, 1882.

a maker of globes, astrolabes[1] of brass and paper, sundials, and compasses.

In 1540 he invented a scale for measuring the calibre of guns. In 1555 he constructed a vertical dial for the tower of the Church of St. Sebaldus, of which he was vicar. He was also the author of an astrological work, the *Directorium*, 1554.[2]

His astrolabes are beautifully finished. I have seen dated examples of the years 1527 (St. John's College), 1537 (British Museum), 1542 (L. Evans collection), 1548 (S. Kensington Museum). There is also a Quadrant with sundial by him at South Kensington, dated 1549.

JOHANNES WAGNER, of Nuremberg.

A contemporary of Georg Hartmann, and like him a maker of planispheric astrolabes with brackets ornamented with 'Tudor' roses of an Italian type. One of his instruments is dated 1538 (L. Evans collection, No. 2025).

J. KRABBE.

Maker of a cardboard astrolabe, dated 1583 (L. Evans collection), which he described in a book.

THE FLEMISH SCHOOL

The leading designers and makers of the sixteenth century in Flanders appear to have been of southern origin. Gemma and Arsenius sound like Italian and Greek names, and the astrolabes of the latter frequently contained Italian *rose dei venti*, or diagrams of the points of the compass.

REGNIER or REINER GEMMA (1508-55).

Born at Doccum in Friesland, and therefore spoken of as GEMMA FRISIUS. Distinguished as a physician, astronomer, and mathematician, he died Professor of Mathesis at Louvain. He was the author of the *De principiis astronomiae et cosmographiae* and of the *De Astrolabo*, Antwerp, 1556.

[1] Described by Franciscus Ritter, *Tract. de Astrolabio.*

[2] Doppelmayr, *Historische Nachricht von der Nürnbergischen Mathematicern und Künstlern*, 1730, p. 56.

CORNELIUS GEMMA.

The son of Gemma Frisius will always be remembered by astronomers as one of the discoverers of the new star in Cassiopeia, now known as 55 Cassiopeae, on 9 November, 1572. It was the only change which had been known to take place in the appearance of the heavens since the revival of learning in Europe and consequently excited the utmost attention. Tycho Brahe, who was astonished at the apparition two days later, 'when returning to supper from his crucibles', was ashamed of publishing his observations on it, considering it 'a disgrace for a nobleman either to study such subjects, or to communicate them to the public'.[1] Cornelius Gemma wrote a 66 page treatise on the Nova. In later controversies our Oxford professor, Keill, took a part. He conjectured it to have a period of 150 years but, alas, it failed to fulfil his prediction.

GUALTERUS ARSENIUS.

Nephew to Reiner Gemma Frisius, and a Louvain maker of astrolabes, that are perhaps more highly prized than those by any other European maker. Besides the great instrument, once the property of Philip II of Spain, dated 1566, smaller dated astrolabes of the years 1565 (L. Evans collection) and 1571 Merton College) are known. See p. 216.

FERDINAND ARSENIUS.

A contemporary instrument maker whose atelier was in Antwerp. There is a specimen of his work, an astrolabe, in the Science Collection at the South Kensington Museum.

CHRISTOPHER SCHISSLER, of Augsburg, *c.* 1552-1606.

A brass worker in a small way at Augsburg, his talents led him to geometry, mechanics, and astronomy. He subsequently described himself as a geometric and astronomical master mechanic (Werkmeister). He made scientific apparatus and automata for the Emperor Rudolph II.

[1] W. H. Smyth, *Bedford Catalogue.*

Of Schissler's work the following dated examples are known:

1552. Instrument resembling a pendent pair of compasses. British Museum.

1554. Box dial, 3 in. in diameter with wind vane, lunar dials, maps of Europe and of the world. British Museum.

1557. Octagonal dial and compass with a map of Europe (water, coloured blue) in the cover. (L. Evans collection.)

1561. Four large sundials on the Perlachthurm in Augsburg.

1569. Quadratum geometricum (his masterpiece) for measuring both elevation and distance.

1578. Dial of Achaz. A beautiful circular basin-dial of Achaz used for calculating nativities; but its indication would only be correct when the basin was filled with water, which by its refraction advanced or retarded the time. Cf. Isaiah 38, 8. The gnomon is held in the left hand of a brass figure representing an ancient astrologer in a turban. The Dial is for latitudes 44–49, elev. poli.[1]

1579. The Geometer's Quadrate in the Bodleian Library.

1581. Sundials with names of English towns, London, Canterbury, Oxford, Bangor, York, Llandaff, Worcester, Winchester, Derby, Exeter, Warwick, and a map of Europe. Miller collection.

1600. A survey of Augsburg which was engraved on copper by Alex. Mair.

1606. Armillary Sphere, formerly in the Stadtbibliothek of Augsburg: now missing.

HUMPHREY COLE. *See* vol. i, p. 173.

VLRICH KLAIBER, Dial maker of Augsburg.

1555. Pocket dial in L. Evans collection.

*** *For Lists of other names of European Makers of Portable Dials and Astrolabes, see pages* 133, 153, *and* 219.

[1] J. F. Sachse, 'Horologium Achaz', *Proc. Amer. Phil. Soc.*, 1895.

VOLVELLES OR ÆQUATORIA

Sun and Moon Volvelles were handy circular scales, by means of which calendrical calculations could be readily performed. The earliest that we have seen dates from before the middle of the fourteenth century, and they appear to have remained in use for some time after the advent of printed books.

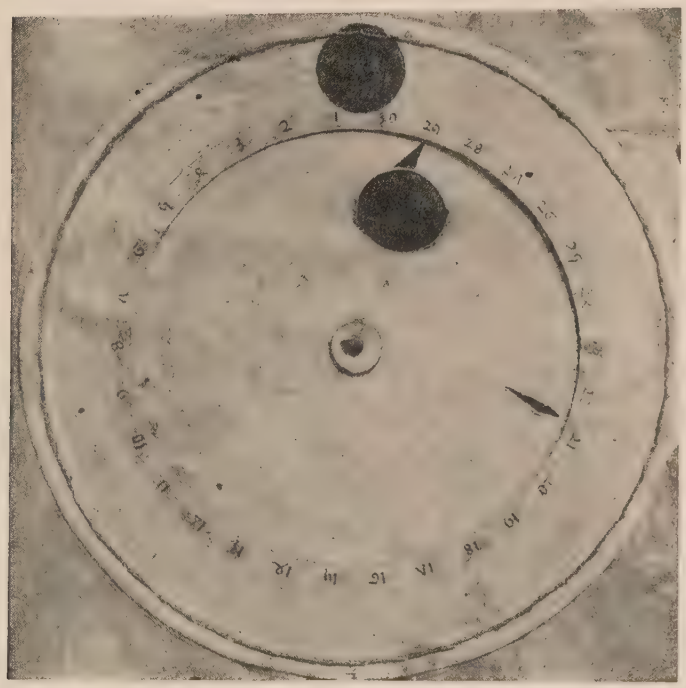
A description of their use is found in *The Rewle of the Volvelle*, MS. Ashm. 191. In a complete instrument there may be as many as seven circles.

The first and outer circle contains the division of the twenty-four hours and also quarters of hours; the second contains the twelve months; the third the twelve signs of the zodiac, with divisions of degrees; the fourth the times, the rising of the sun and moon; the fifth the meridian altitude with degrees; the sixth the age of the moon; the seventh and last shows the aspects of the sun and moon.

The early Æquatoria of John de Lyners and of Profacius have been mentioned on page 31. Dr. J. L. E. Dreyer has courteously written me the following note upon them. 'Æquatoria are systems of graduated disks used for finding approximate places of sun, moon, or planets without the use of tables, the latitude being quite ignored. Thus, in Vol. III of the *Libros del Saber* there are two tracts, "Two books on the lamina of the seven planets". The deferent or excentric circle is graduated by laying down equal angles from the punctum æquans (seen from which the motion on the deferent is uniform). The longitude of the epicycle-centre from the apogee (in the Alfonsine Tables, called the centrum) was first marked on the circumference of the deferent, the centre of the epicycle placed on the point thus marked; the arc of the epicycle from its apogee to the planet (the argument) was laid down, and finally the alidade from the place of the earth through the planet indicated the place of the planet seen from the earth on the graduated outermost circle, the ecliptic.'

One Volvelle of metal is preserved in the Merton Library and is described on page 241, but the greater number of the oldest Volvelles in Oxford are contained in manuscripts and are made of parchment.

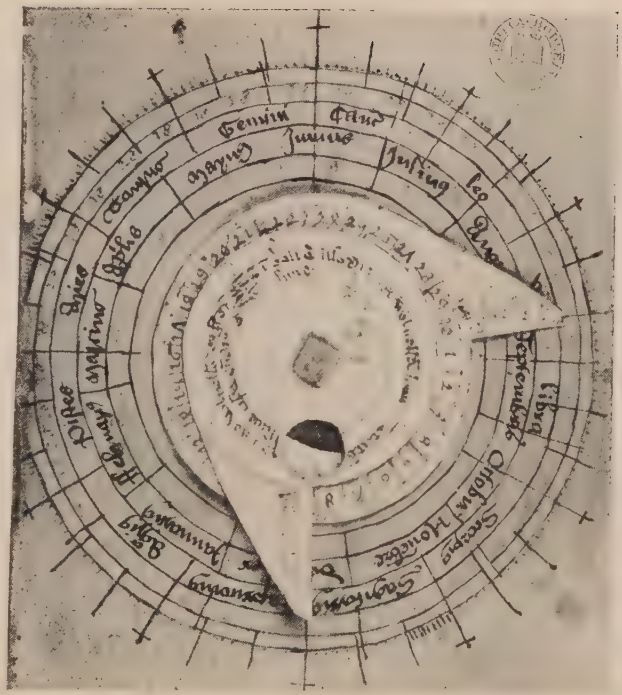
86. Volvelle. **Before 1350.**
MS. Ashmole 1522, f. 87.



No. 87.

87. Volvelle. **c. 1386.**
MS. Ashmole 210.

The moon dial showing the phases can be rotated beneath a circular flange of parchment stitched with blue and yellow thread on to the leaf of the book.



88. Volvelle. c. 1390.
Diameter $4\frac{1}{2}$ inches. MS. Bodley 68 (S. C. 2142), f. 46.

89. Volvellae solis et lunae.
MS. Digby 167, f. 31.

In the early fifteenth-century book of John Enderby of Louth and later of Chaunteler de Oxon.

No. 90.

90. Volvelle. 1424.

MS. Ashmole 370, f. 25.

Parchment in perfect order. Diameter $5\frac{1}{2}$ inches.

91. Volvelle. c. 1440.

MS. Ashmole 191, ff. 53^{b}, 199, 211.

92. Volvelle (unfinished). 14—.

MS. Ashmole 369, f. 1^{b}.

No. 93.

93. Volvelle.

Parchment. Diameter 5 inches. MS. Ashmole 789, f. 363. Perfect. Coloured, red, blue, and gold. On the same page as a Zodiac man.

94. Volvelle, similar to **93**.

MS. Savile 39, f. 7.

No. 95.

95. Volvelle. **Edw. IV.**

MS. Ashmole 1448, f. 278.

96. Volvelle. **1460–2.**

MS. Ashmole 391, f. 7.

Coloured parchment. Diameter 6 inches.

The two pointers are marked 'volvella lune' and 'volvella solis'. The rule is written on the upper movable circle in a spiral direction from the edge to the centre; beg. *Pone volvellam solis.*

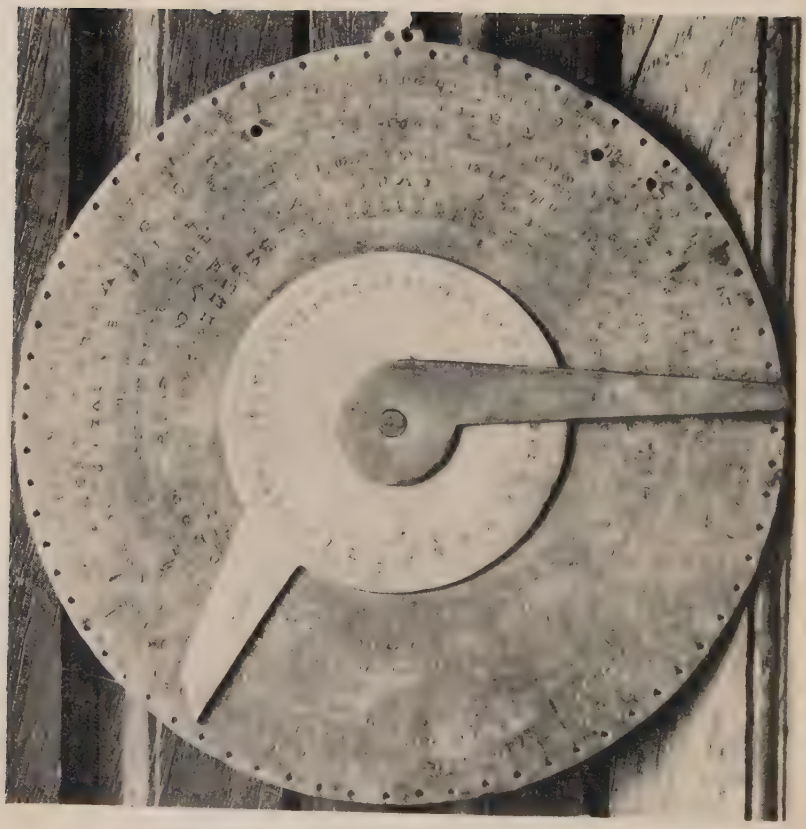
No. 97.

97. Volvellae lune et solis. 15th cent.
Diameter $4\frac{3}{4}$ inches. MS. Digby 48, f. 203.

98. Volvelle. 15—.
MS. Ashm. 1483, f. 77 b.
Constructed to illustrate a work by Raymond Lully.

68. Volvelle or Circular Scales for Lunar and Solar Calculations. Quadrant and Zodiac Man.
c. 1400–50.
Diameter $6\frac{1}{8}$ inches. Merton College.
Graffito: C. . . .

A composite instrument built upon a circular disk with a small triperforate bracket for suspension. The



NO. 68. VOLVELLE ON BACK OF THE PHYSICIAN'S QUADRANT

Merton College

circumference is drilled with seventy-two perforations, perhaps for reading or setting the pointers in the dusk. The circles are now held together by a copper rivet, which may have replaced a tubular pin. If so the instrument would have been a nocturnal, or *instrumentum siderale*.[1] The incised lines and figures upon the instrument are of two periods: the older being filled with red colour, the later additions with black.

On the back of this instrument are nine circles, the month circles being slightly eccentric to the rest. Counting from the outside they are:

1. Circle of 72 perforations at 5° intervals, perhaps for use at night.
2. Circle of degrees of the Zodiac.
3. Circle of divisions ♃. 10. ♃. 20. ♃. 30 of the signs of the Zodiac.
4. Names of the signs of the Zodiac.
5. Names of months arranged on no intelligible plan. January being opposite 29 of Pisces. Between the names are numbers:

15 IA 15	9 IVL 9
14 FE 14	10 AVG 11
13 MAR 12	11 SEP 12
11 APRI 10	12 OCTO 13
8 MAI 8	13 NOVE 14
8 IVN 8	15 DE 16

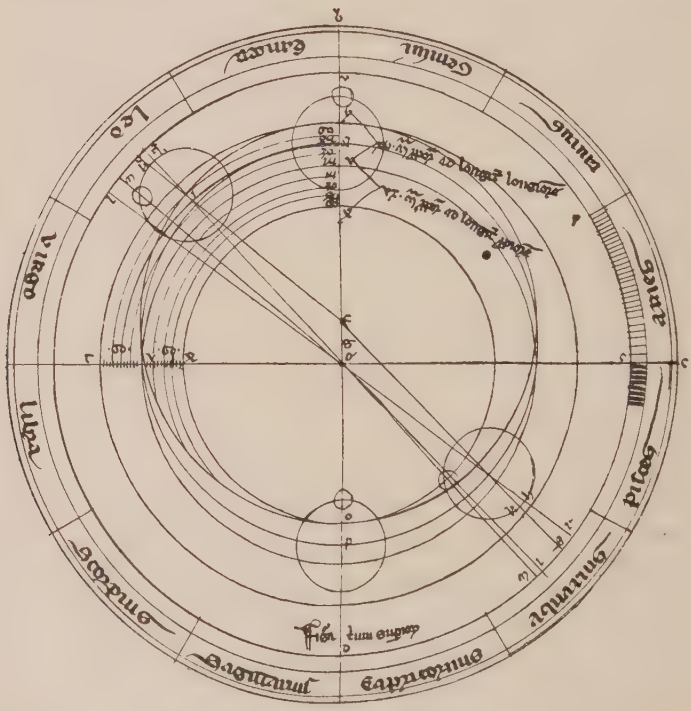
6. Circle divided into days of the months.
7. Numbers of days of month, by fives.
8. Names of Months in their proper positions as regards the zodiac.
9. Circle of numbers, 0 being opposite the first points of Aries and Libra, 24 opposite the first points of Cancer and Capricorn, and between these seventeen other numbers, some, e.g. 22 and 23, repeated, but more omitted, e.g. the odd numbers 3, 7, 9, 11, 13, 17.

In the middle is a rotating dial, $2\frac{3}{4}$ in. diam., bearing a pointer, the index solaris, marked SOL, and with the periphery divided into $29\frac{1}{2}$ parts for the days of the lunar month. Above this lunar disk moves a longer rotating index marked LUNA, which is the *index lunae et aspectum*. Both indices reach the outer edge of the instrument.

[1] Cf. Gemma Frisius, *Cosmogr.*, f. 50, ed. 1545.

The use of the dials is partly explained by Jordan,[1] 'horometri tergum in quo verus solis locus singulis diebus prope verum colligere licet cum aspectibus'. But the haphazard arrangement of names and numbers may have a magical rather than a scientific significance.

The first point of Aries corresponds with the 13 March, or a more coarsely drawn line near by with the 11 March.

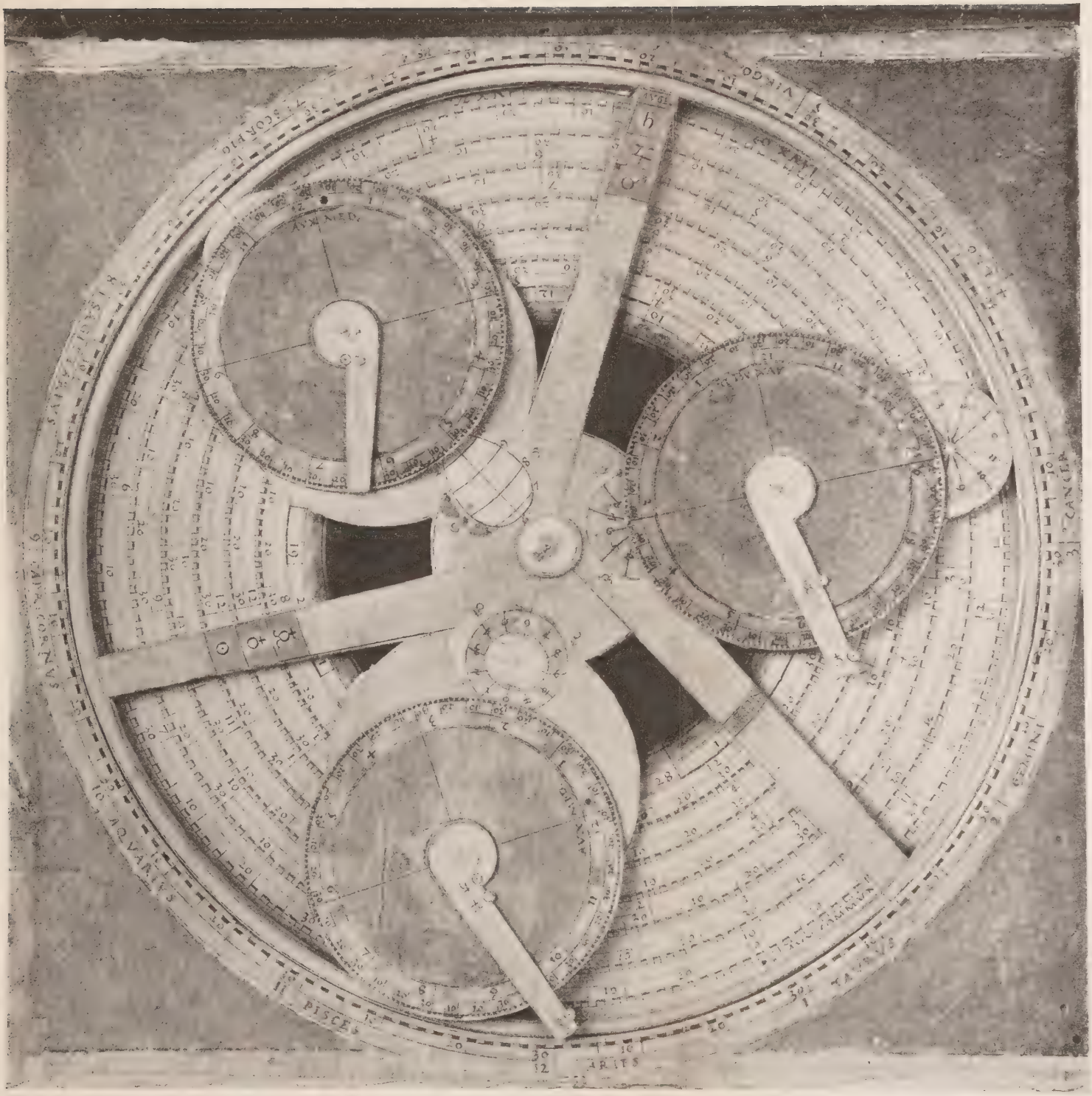


MS. Ashmole 1522, f. 106.

Planetary Volvelles or Aequatoria

Volvelles designed to illustrate the motions of the planets are occasionally found in astronomical treatises. An example of such a planetarium, $3\frac{1}{2}$ inches in diameter, of about the period 1433–60, is in MS. Digby 48, f. 113.

[1] *Fabrica astrolabii*, 1535.



PLANETARY VOLVELLE, C. 1552

MS. Savile 100

Peter Apian[1] made such a model on a larger scale, by which he represented the epicyclical motions of the planets by means of movable circles of cardboard of various colours, and expected by such means to be able to find their positions without computation. This model interested the Landgrave Wilhelm IV of Hesse so greatly that he had circles of copper made for the same purpose. He found considerable errors in existing star catalogues, and became convinced of the necessity of making systematic observations. With Tycho he redetermined the position of Spica virginis.

Something of the same kind may be seen in the wonderful instrument book, MS. Savile 100, which is, so far as we know, as yet undescribed. See p. 386.

99. Planetary Volvelle. 1552.

10 inches in diameter. MS. Savile 100, f. 8.

An elaborate cardboard instrument for setting out the positions and courses of the Planets. Within a Zodiac circle of the twelve Signs, on a raised rim, are seven circular scales of the auges of the planets, Saturn, Jupiter, Mars, Sun, Venus, Mercury and of the 28 'Mansiones ☾'. Over these rotates a cardboard wheel with six spokes, three of which are enlarged to carry three adjustable circles, with indices and rims divided into 12 Signs, each subdivided into 30 degrees. The indices are marked to show the motions of Jupiter, Saturn and Mars, of Venus and Mercury, and of Sun and Moon respectively. See plate facing p. 243.

The splendid folio work of I. P. Gallucius, *Speculum uranicum*, 1593, is illustrated with very numerous volvelles, one for each of the planets.

In a more modern guise the old planetary volvelle reappeared in the seventeenth century as the Planetary Instrument.

Planetary Instrument. 1672.

By Walter Hayes, at the *Cross-Daggers* in *Moor-Fields*.

The instrument was described in an illustrated pamphlet of six pages, by John Palmer, Rector of Ecton and

[1] Peter Apian's *Astronomicum Caesareum*, 1540, a large book dedicated to Charles V.

Archdeacon of Northampton. The instrument was 'drawn in true *Proportion*, either in one, or two Plates, of eight inches Diameter. . . . Being excellent Schemes to help the Conceptions of Young *Astronomers*; and ready Instruments for finding the *Distances*, *Longitudes*, *Latitudes*, *Aspects*, *Directions*, *Stations* and *Retrogradations* of the *Planets*; either *Mechanically* or *Arithmetically*; with Ease and Speed.'

This instrument was stated to be an improvement on that of S. Foster, in which the planets were disposed in *four* plates.

Some copies of this pamphlet were sold by Hayes as an Appendix to J. Twysden's *Use of the General Planisphere.*

MS. Digby 17, f. 151 v.

ASTRONOMICAL MODELS

LOBES have always been regarded as part of the furniture of a good library, and for those who have been trained in their use, very varied and readily accessible is the information they convey. Terrestrial globes, though more generally considered as geographical than as astronomical models, are also included in our review, on account of the obvious inconvenience of divorcing the two components of a Pair of Globes.

It is quite the usual fashion in Oxford to furnish libraries with a pair of Globes. The practice can boast a respectable antiquity, for it has been handed down from the centres of Greek and Arabian learning. The Cairo Library, containing 6,500 manuscripts on astronomy and medicine, was equipped with 'two fair globes, the one of brass, the other of silver', *c.* A.D. 800 (Gibbon). These were probably celestial spheres; and celestial globes were made long before terrestrial globes. Anaximander (born *c.* 610 B.C.) is said to have constructed a sphere to represent the heavens. A marble globe that may have been the work of the famous astronomer Eudoxus (d. 386 B.C.) is preserved in the Museum at Naples. The globe, supported upon the shoulders of Atlas, is 2 metres in diameter. The constellations engraved upon it indicate that it dates from the fourth century B.C.[1]

Aratus of Soli in Cilicia, if one can believe a poet, appears to have been the owner of a celestial globe, which is mentioned in his *Prognostics of the Stars and the World,* a short poem that was imitated by Virgil.

Archimedes was the possessor of a celestial globe of glass in the centre of which was a small terrestrial globe, and a similar apparatus is believed to have belonged to Hero of Alexandria (284–221 B.C.).

[1] E. Heis, *Atlas coelestis novus*, Bonn 1872.

Hipparchus (*c.* 150 B.C.) made a celestial globe on which he showed the positions of a considerable number of the fixed stars as determined by him. Ptolemy saw it in the Alexandrian Library.

Crates of Miletus (d. 145 B.C.) illustrated the geographical views of the Stoics by a globe, on which the habitable land is divided by equatorial and meridional oceans into four quarters, 'thus anticipating the discovery of North and South America and Australia'. This globe of Crates has survived in the orb, which has become one of the insignia of royalty.

The first book on the manufacture of globes is attributed[1] to Leontius, Bishop of Neapolis (Cyprus) of the time of Constantine III (A.D. 642–68). It was printed at Basel in 1539.

After the time of Bede when celestial globes formed part of the educational apparatus of monastic schools, globes were made in 929 by Gerbert of Aurillac and by the skilled craftsmen employed by Alphonso the Wise who described their manufacture in 1252. They were necessary for the demonstration on the Sphere of G. Campanus of Novara, *De sphaera solida 1303*. But there is no record of any terrestrial globe at this early time.

The Arabs likewise produced celestial globes only. Korra ben Kamita al-Harrani made a globe for which Tobit ben Korra took the credit.

It was composed of some rough, unbleached fabric from Dabik, and painted, but the colours had already faded when Ibn Abi Jakub an-Nadim saw it (*c.* A.D. 987).[2]

Bronze Globes.

The oldest Arabian globe now extant, made at Valentia, is to be seen in the Museum at Florence. The dates of others are known from the inscriptions upon them.

A globe at Velletri is of 1225. Ibn Hula of Mosul's globe of 1275 is in the possession of the Royal Asiatic Society of London. A globe of 1289 from the Maragha

[1] Fiorini.

[2] Cf. *Kitab al-Fihrist.* Suter's translation in *Zeitschr. Math. Phys.*, Suppl. to vol. 37.

Observatory is in the Dresden Museum. Two ancient Arabian bronze globes in the Bibliothèque Nationale, Paris, are of uncertain age.

In Oxford we have on exhibition a fine example of an Arabic globe, which is being offered to the University by Mr. Lewis Evans with his collection of scientific instruments and sundials.

It has been recently examined by Mr. E. B. Knobel, who has supplied the following account of the Cufic inscriptions upon it. He notes that all the constellations are Ptolemy's, and that he has been able to obtain a most satisfactory confirmation of the date by the longitudes.

Cufic Arabic Globe. **A.D. 1362.**

Lewis Evans Collection.

Bronze, six inches in diameter; with engraved figures of the constellations and stars represented by inlaid silver disks, corresponding in size to the magnitudes of the stars. Supported by a four-legged, circular stand on which its axis can be adjusted.

Made by Jaafar ibn Omar ibn Dauletshah al Kermani in the year 764 Hegira, 732 Yezdegird, 1674 Alexander. The positions of the stars taken from the 'Description of the Stars' by Al Hussain Abd al Rahman al Sufi. The longitudes increased by 5° 38′.

There is a movable axis which can be adjusted to the Pole of the Equator, or to that of the Ecliptic—and further adjustments to every 10° of North Latitude. The Figures of the Constellations are well drawn and similar to those on the Borgia Globe described by Assemanus, but in the reversed position to the figures in Manuscripts of Al Sufi.

Northern Constellations

URSA MINOR	= Dubb al Âsgar.	DRACO	= Al Tinnin.
Al Djudai.	Polaris.	Al Raqis.	μ Draconis.
URSA MAJOR	= Dubb al Akbar.	CEPHEUS	= Qifaus.
Djaun.	ε Ursae Majoris.	Al Ra'i.	γ Cephei.
A'naq.	ζ Ursae Majoris.	BOOTES	= Al A'uva.
Suha.	Alcor, companion to η.	Simak Al Ramih.	Arcturus. α.
Qafzat Al Ula.	ξ Ursae Majoris.	CORONA	= Al Fecca.
Qaid.	η Ursae Majoris.	Al Nair.	α Coronae.

HERCULES	= Al Djatsi al Rukbatihi.	
Al Nasaq al Schamai.	Group of stars series of Syria.	
LYRA	= Al Sulhafa.	
Nesr al Waqi.	α Lyrae. Vega.	
CYGNUS	= Al Dadjadja.	
Ridf.	α Cygni.	
CASSIOPEA	= Dzat al Kursi.	
Kaff al Chadhib.	β Cassiopeae.	
PERSEUS	= Barschausch.	
Ras al Ghul.	β Persei.	
Mi'sam.	χ Persei.	
AURIGA	= Mumsik al Ai'nna.	
A'iouq. Capella.	α Aurigae.	
OPHIUCHUS	= Al Haiyah.	
SERPENS	= Al Houa.	
SAGITTA	= Al Sahm.	
AQUILA	= Nesr al Tair.	
	α Aquilae.	
DELPHINUS	= Al Dulfin.	
EQUULEUS	= Qita' al Feras.	
PEGASUS	= Al Feras al A'zham.	
Al Farg al Muqaddam.	α and β Pegasi.	
Al Farg al Muachchar.	γ and δ Pegasi.	
ANDROMEDA	= Marat al Musalsala.	
Rascha.	β Andromedae.	
TRIANGULUM	= Al Muthallath.	

Zodiacal Constellations

ARIES	= Surat al Hamal.	
Scharatain.	β and γ Arietis.	
TAURUS	= Surat al Thaur.	
Al Thaur.	Taurus.	
Debaran.	α Tauri.	
GEMINI	= Surat al Tavamain.	
Al Djauza.	Gemini.	
Al Hana't.	γ and ξ Geminorum.	
CANCER	= Surat al Sartan.	
Al Sartan.	Cancer.	
LEO	= Surat al Asad.	
Caucab al Asad.	Stars of Leo.	
Al Sarfa.	β Leonis.	
VIRGO	= Surat al A'dzra.	
Al Simak al A'zal.	α Virginis.	
Al A'uva.	β, η, γ, δ, ε, Virginis.	
LIBRA	= Surat al Mizan.	
Al Zubana.	α and β Librae.	
SCORPIO	=	
Al A'qrab.	Scorpio.	
Al Iklil.	β, δ, π, Scorpionis.	
Al Schaulat.	λ, υ, Scorpionis.	
SAGITTARIUS	= Al Qaus.	
CAPRICORNUS	= Surat Al Djedi.	
Al Djedi.	Capricornus.	
AQUARIUS	= Surat Sakib al Ma.	
Al Dalv.	Aquarius.	
PISCES	= Surat al Samkatain.	

Southern Constellations

CETUS	= Surat Qitus.	
Al Na'amat.	τ, υ, ζ, θ, η, Ceti.	
ORION	=	
Ridjl al Djauza.	β Orionis.	
Al Haqa'.	λ, ϕ^1, ϕ^2, Orionis.	
ERIDANUS	= Al Nahr.	
Achr al Nahr.	θ Eridani.	
LEPUS	=	
Al Arnab.	Lepus.	
CANIS MAJOR	= Kalb al Akbar.	
Schi'ra al Yemenia.	Sirius.	
	α Can. Maj.	
CANIS MINOR	= Schi'ra al Schamia.	
Procyon.	α Can. Min.	
Al Mirzam.[1]	β Can. Min.	

[1] The name 'Al Mirzam' is given by the Arabs to stars preceding a bright star.

CUFIC ARABIC GLOBE, 1362

Lewis Evans collection

ARGO	= Al Safina.	
Al Suhail.	Canopus.	
	α Argus.	
HYDRA	= Al Schudja'.	
Fard.	α Hydrae.	
CRATER	= Al Batiya.	
CORVUS. ?		
CENTAURUS	= Qentaurus.	
Rigel Qentaurus.	α Centauri.	
LUPUS	= Al Sabu'.	
ARA	= Al Midjmara.	
	Ara.	
CORONA AUSTRALIS. ?		
PISCIS AUSTRINUS	= Hut Al Djenubi.	
Al Dhifda.	α Piscis Austr.	
Fam al Hut.	α Piscis Austr.	

Inscription at North Pole of Equator

Cutb mua'ddil nehar Al Schemali = Pole of equal day North. North Pole of equinoctial.

Inscription at South Pole of Equator

Cutb mua'ddil nehar Al Djenubi = Pole of equal day South. South Pole of equinoctial.

Difference of longitude of stars with Al Sufi

α Leonis	5° 38′
α Virginis	5 38
α Scorpii	5 38
β Geminorum . . .	5 38
α Aurigae	5 18
α Bootis	5 18
α Piscis Austrinus . .	5 18

Taking 51″ as the constant of Precession, as adopted by Ibn al Alam, then 5° 38′ = 20280″ ÷ 51 = 398 years.

Epoch of Al Sufi A.D. 964 + 398 = A.D. 1362.

Globe dated 764 Hegira = 732 Yezdegird = 1674 Alexander = A.D. 1362. [E. B. K.]

In China the Ho-shing-tien Celestial Globe, 4 metres in circumference, was made in 450.

Yhang manufactured a Celestial Globe, *c.* 721.

Celestial globes were part of the necessary apparatus for the adequate demonstration of the theories of early astronomers. They were made and used by Regiomontanus (1436–76) at Nuremberg, by Johannes Stöffler (1449) of Tübingen, and by George Hartmann (1489–1535). About 1595 the great celestial globe that has become historic, was made for Tycho Brahe at Augsburg at a cost of about 5,000 daler.[1] For the names of a few later makers also see p. 264.

[1] Dreyer, *Tycho Brahe.*

Terrestrial Globes

The **Terrestrial Globe** was a much later invention than the Celestial Globe, although it was early known to many men of science that the Earth was round.

The theory of the sphericity of the earth, advanced by the Pythagoreans and rightly held by Aristotle, was revived by Roger Bacon and by his rather older contemporary Albertus Magnus of Swabia in the thirteenth century, and again by the Cardinal d'Ailly (d. 1422) whose work *Imago Mundi* has acquired an enhanced importance because it is known to have been in the possession of Columbus (1446–1506).

Terrestrial globes first appear in use about the time of Columbus, and very imperfect they were, but their inaccuracies supplied an incentive to the first navigators of the uncharted oceans.

Such topographic details as could be relied upon were partly supplied from *portolani* or charts of the Mediterranean. They were more accurate than any other maps of their day, and were used by the seamen of that sea long before the use of the compass was known in Europe. These charts were based on estimated bearings and distances between the principal ports and capes and were covered with radiating 'loxodromes', or lines to help the seaman to get his bearings. They were in use as early as 1205, according to Guiot de Provins, whereas the mariners' compass does not appear to have been generally available for navigation in European seas before the beginning of the fourteenth century.

The introduction of degree-lines upon early maps followed on the translation of Ptolemy into Latin by Jacobus Angelus de Scarparia in 1410. And soon after, Cardinal Nicolaus Krebs of Cusa on the Moselle (d. 1464) drew a map of Germany, which was first published in 1491.

Such were some of the scanty materials ready to hand for the first terrestrial globe makers. Two of the very oldest globes that are now extant are the Laon and the Nuremberg globes.

The Laon globe is copper gilt, and $6\frac{3}{4}$ inches in diameter. In spite of a legend that it presents the results

of the Portuguese explorations up to 1493, it is of more ancient date.

The designer of the Nuremberg globe, Martin Behaim, had resided for six years in Portugal and the Azores. It is of pasteboard covered with whiting and parchment and is 23 inches in diameter. The positions of countries have for the most part been taken direct from Ptolemy and are accordingly inaccurate; and although Behaim had lived in Portugal, he did not incorporate the wonderful discoveries of the Portuguese navigators, but he did indicate the southern end of Africa in accordance with the result of Diaz's voyage of 1486. The ocean which separates Europe from Cathay is only 126° wide in accordance with Toscanelli's ideas of 1474.

For their latitudes the early geographers had to rely upon mariners' observations with the astrolabe, quadrant, and cross-staff, and no accurate longitude observations were possible before the publication of Kepler's Rudolphine Tables (1627). Moreover, the variation of the compass caused trouble which one early cartographer, Pedro Reinel, tried to get over by the introduction of two scales of latitude on his chart of the North Atlantic in 1504.

One of the minor results of the discovery of America was the extension of the use of globes both celestial and terrestrial. Columbus and Drake used globes as part of the scientific equipment of their ships. Lectures at the University of Vienna were illustrated with the help of globes by Conrad Celtes in 1501. Pedro Reinel's globes (1519) were used by Magellan on his Voyage.

Until this time globes had been principally made of bronze or copper, upon which the countries and parallels and meridians were engraved or painted. But in 1507 a new departure was made. Waldseemüller (1470–1521) published a small globe of a diameter of $4\frac{1}{2}$ inches, the segments for which were *printed* from wood-blocks. Upon this globe America ('C. de Cortereal') is shown separated from Asia by a considerable ocean.

The advantages of so cheap and expeditious a method were at once apparent, and many makers on the continent produced globes covered with printed gores.

GLOBE MAKERS OF THE EARLY SIXTEENTH CENTURY

'Lenox' Globe 1508–11 (engraved) 4½ in. diam. New York.

L. BOULENGER 1514.

JOH. SCHÖNER 1515, 1523, 1533, and another painted by hand about 2½ ft. in diameter in the Nuremberg Museum.

GEMMA FRISIUS 1530.

'Nancy' Globe, chased silver, 6½ in. diam. *c.* 1530.

ROBERT DE BAILLY, *c.* 1530, engraved copper and gilt, 18 in. diam.

G. MERCATOR, 1541, 16 in. diam.

PHILIP APIAN. *c.* 1570.

LEONARDO DA VINCI about 1515 drew a rough map of the world in 8.

It is popularly believed that the earliest terrestrial globe made in England was that of EMERIC MOLYNEUX in 1592 of which an example 2 feet in diameter was recently to be seen in the library of the Middle Temple.[1] But portraits of early British circumnavigators as, for instance, the portrait of Sebastian Cabot[2] or the later engravings of Francis Drake indicate that globes were not unfamiliar to previous generations. It is, therefore, not remarkable that Merton College should be said to have possessed globes much older than the Molyneux. The question is, Were they of English manufacture?

In the seventeenth century many globes were published by the firm of Blaeu—founded at Amsterdam in 1612 by WILLEM JANSZON BLAEU,[3] a friend and pupil of Tycho Brahe, and a man of scientific culture. To him succeeded his son, JAN (d. 1673), and grandson, CORNELIUS, well known for the hundreds of maps which they published.

In England 'great globes' made by William Saunderson were justly to be 'preferred before all other that have

[1] It was one of the pair referred to in Blundeville's *Exercises*, 1594. The first suggestion of a Relief Globe is contained in a letter of M. Maestlin to J. Kepler in 1596.

[2] At Whitehall in the time of James I (Green).

[3] Willem Blaeu died in 1638. There are globes of about this time in the Ryks Museum, Amsterdam, in the British Museum, and in the Court Room of Trinity House. See *Country Life*, 26 April 1919.

been set forth before them, as being more capacious then any other, for they are in diameter two foot and two inches; whereas Mercator's globes are scarcely sixteen inches diameter'. They appear to have led to the publication in 1639 of an English translation of Robert Hues' book on Globes by JOHN CHILMEAD, M.A. of Christ Church, whom Bloxam believed to be the same as Edmund Chilmead, Clerk of Magdalen College. In any case he appears to have been the first Oxford man to write on Globes in the modern sense.[1]

Milton considered it 'seasonable to learn the use of the Globes' for those engaged in the study of fortification, and Lord Herbert of Cherbury, who had come up to University College at the age of thirteen, approved of the use of the celestial globes although he did 'not conceive yet the knowledge of judicial astronomy so necessary, but only for particular predictions'.

During Milton's lifetime the sale of globes was doubtless already being stimulated by advertisements in journals and publications: the following one appeared in the very year of his death in the *Philosophical Transactions* of the Royal Society, 27 April 1674, p. 40.

An *Advertisement* about a New size of *Globes* rectified.

There is lately set forth a New size of Globes about 15 Inches diameter, Celestial and Terrestrial. In the former, *not only the Right Ascensions and Declinations of several Stars are rectified, but the Constellations are so faintly and curiously represented, that the First Stars appear much more conspicuous, than in any other extant: In the* latter *there is scarce any part of the Earth, wherein a considerable alteration hath not been made; so that* Asia *and* America *are in a manner new, and much different from what hath been hitherto drawn upon a Globe: The Eastern part of* Asia *rectified more than 10 degrees; and many places in* Europe, Africa, *and* America *more than 5 degrees; many eminent Towns inserted, that were wholly omitted in others: The Longitudes and Latitudes of most places being now corrected and adjusted not only by late Discoveries, but also by Trigonometrical Calculation, and the more accurate Celestial Observations of modern Authors; the names of whom, together with a further account of the Reasons of such differences and alterations*

[1] J. Chilmead. *A learned Treatise of Globes, both Coelestiall and Terrestriall: with their severall uses.* 8vo. London 1639.

shall be more at large expressed in a Treatise designed for the Use of these Globes by R. Morden *at the* Atlas *in* Cornhill, *and* William Berry *at the* Globe *between* York-house *and the* New Exchange *in the* Strand, London; who are the two persons that sent in this Advertisement.[1]

Several notable globes of large size were made in the seventeenth century, for instance

In 1623 by V. Coronelli for Louis XIV. Diameter 15 feet.

1656–64 by A. Busch for Duke Frederick of Holstein. Diameter 11 feet. Since 1713 at Tsarskoye Zelo.

1696 Erh. Weigel made a hollow celestial globe in copper having a small terrestrial globe in its centre. Diameter 14 feet.

In the eighteenth century we have the commercial globes which became common, published by J. Senex, author of the *Atlas* of 1725, and by E. and G. Adams 1710–66. In France globes were manufactured by the following makers:

1700 Guillaume Delisle (1675–1726). 1710–31 Forbin.
1752 R. and J. de Vaugondy. 1771 Lalande.
And in Germany: 1750 Homann and Seutter.

The large globe, 18 ft. diameter, set up in Cambridge by Dr. Roger Long was far surpassed by the 85-foot globe presented to Louis XVI in 1787 by Count Ch. Gravie of Vergennes.

In the nineteenth century this record was again beaten by the 127-foot globe built in the Champs Elysées in 1824 by Colonel Langlois. And about the same time one of the sights of London was James Wyld's 'Georama', a hollow globe, in Leicester Square; it was close on 60 feet in diameter.

Globes in Oxford Collections

Two Globes. 1567.

Merton College.

Received in exchange for an organ from the Chapel.

The date 1577 is given for the transaction by Wood, MS. Bodley 594, f. 144, whereas Pointer, p. 27, gives 1677.

Pair of 8-inch Globes by I. Hondius. 1615.

Vernon Watney Esq., Cornbury Park.

Supported by bronze figures of Atlas on porphyry bases. The Horizon circle is engraved with two circular calendar-scales for Old and New styles. 1st of Aries = 11th March.

[1] *Philosophical Transactions*, 27 April 1674, p. 40.

100. Monumental Globe. Southern hemisphere only. 1624.

On monument to Sir H. Savile in Merton College.

By Nicholas Stone.

The oldest globe now extant in Oxford. A dotted line represents the route of some early voyager who rounded the Cape of Good Hope.

Large Ornamental Globe. c. 1688.

In 'Mercury', Quadrangle of Christ Church.

Loggan's engraving shows it to have been ruled with lines of latitude and longitude and with the ecliptic. It may have served as a sundial. See p. 109.

102. Terrestrial Globe. ? 1710–14.

Diameter 17 inches. Brasenose College.

Inscribed—

Philosopho ac Geometrae summo
Do Isaco Newton, Equiti,
Regalis Societatis Londini
ad scientias promovendas institutae
Praesidi dignissimo
Ejusdem Consilio et Sodalibus
Hos Globos qua par est humilitate
D.D.C.
Carolus Price
Johannes Senex

Sold by Cha. Price
In. Senex Ias. Maxwell
London.

Newton to whom this globe was dedicated while President of the Royal Society, held that office from 1703 until his death in 1727.

According to the *Dictionary of National Biography*, Senex 'printed with C. Price, probably in 1710, "Proposals for a New Sett of Correct maps". In that year he issued with Price and John Maxwell maps of North America and Germany and in 1712 one of Muscovy. They appeared collectively in 1714 as "The English Atlas" under the joint names of Senex and Maxwell.' It therefore looks as if Price had fallen out of the partnership before 1714. He also seems to have been Senex's predecessor, for the Royal Geographical Society owns a Globe (16 in. diam.) dedicated by Price only to

Sir I. Newton as President of the Royal Society. But this too is undated. The probability would therefore seem to be that the B.N.C. Globe was made somewhere about 1710–14.

103. 12-inch Terrestrial Globe. 1716.
Oriel College.

In poor condition.

A New & Correct
Globe of ye Earth
Together with a view of General &
Trade Winds, Monsoons &
laid down according to ye nearest
discoveries and from ye Most Exact
Observations
By John Senex
Sold only by him at the Globe in
Salisbury Court near Fleet Street
1716

104. A New and Correct Globe of ye Earth. c. 1716.
Diameter 12 inches. Brasenose College.

By John Senex. Sold by him at the Globe in
Salisbury Court Fleet St.

Mention of Senex Globes of 16, 12, 9, and 3 inches diameter as already on the market is made in a *Treatise of the Description and Use of Both Globes* 1718. Also there is an announcement, as shortly to be published, of 'A new Pair of Globes of 26 in. diameter'. Whiston's *Scheme of the Solar System* speaks of 'Ye newest globes of 16, 18, and 3 in. diameter' and states that Senex has just finished in a most elegant manner a Pair of 28 in. diameter. A terrestrial globe of 1720 is in the British Museum.

At the Globe in Salisbury Court Senex engraved the plates for the London Almanacs from 1717 to 1727 as well as the cuts for the second edition of Sir Wm. Browne's *Account of Microscopes and Telescopes*. Maps by him appeared in 1710–22. In May 1738 he read a short paper to the Royal Society on his *Contrivance to make the poles of the diurnal motion in a Celestial Globe pass round the poles of the ecliptic.*[1]

[1] *Phil. Trans.*, 1738, No. 447.

105. Small Terrestrial Globe. 1731.

Diameter 3 inches. Christ Church.

By R. Cushee.

Attached to the Orrery by Wright.

Richard Cushee was an engraver who was nearly related to E. Cushee, Globe maker at the Globe and Sun between St. Dunstan's Church and Chancery Lane, who was the publisher of Joseph Harris's *Description and Use of Globes*, 4th edit. 1738.

Shortly before his death in 1749 John Senex, who had become an F.R.S. in 1728, began to advertise his wares still more extensively, with the result that either by gift or purchase several found their way into the Colleges at Oxford.

At the end of Thomas Wright's, of the City of Durham, *The Use of the Globes or, The General Doctrine of the Sphere*, London, Printed for John Senex over-against St. *Dunstan's* Church in *Fleet-street*, 1740.

A Catalogue *of* GLOBES and MAPS, *made and sold by JOHN SENEX*, Fellow of the ROYAL SOCIETY; *at the* Globe, *against St.* Dunstan's *Church in* Fleet-street, *London.*

'A Pair of Globes 28 Inches Diameter, fit to adorn the Libraries of the Curious. On the Terrestrial are inserted all the Discoveries and Observations hitherto made; and on the Celestial, are placed all the Stars in Mr. *Flamsteed's Catalogue*, as published by Dr. Halley, etc., being above 2000 more than ever were inserted upon any Globe. The Asterisms are designed so as to answer the Description of the Antients, and the Letters of Reference made use of by *Bayer*, in his Tables, are inserted. The Price of these handsomely fitted up is 25 Guineas.'

A pair of Globes of 17 Inches Diameter, from the latest Observations. Price 6*l.*

A pair of Globes of 12 Inches Diameter, from the latest Observations. Price 3*l.*

A pair of Globes of 9 Inches Diameter, from the latest Observations. Price 2*l.*

A Pocket Globe 3 Inches Diameter, the Celestial being the Case to contain it. Price 10*s.*

There is a globe of 12 in. diam. by John Senex in the S. Kensington Science Collection, dated 1738.

106-7. Pair of Large Globes. 1740.

Diameter 2 feet 3 inches. Queen's College.

By Johannes Senex, R.S.S.

Presented by Walter Edward Freeman in 1747.

GLOBUS
TERR-AQUEUS
omnes Regiones hactenus
exploratas exhibens secundum
nuperas Observationes Astro-
nomicas
et Navigantium ac Itinerarium
fide digniorum relationis con-
sectum
Opera Johan: Senex
R.S.S.

GLOBUS
COELESTIS
quo exhibetur Coelum Sydereum
juxta Observationes Astrono-
morum
recentiorum quantum fieri potuit
accurate descriptum
In hoc Stellae ultra bis mille
plures
quam in quovis e globis prioribus
reperiuntur. Asterismi autem ad
mentem Veterum delineantur
In Annum 1740
Opera Johannis Senex
R.S.S.

108-9. Terrestrial and Celestial Globes. 1740.

St. John's College.

By Johannes Senex, R.S.S.

Presented by George Scot.

110-11. Pair of Large Globes. 1740.

Merton College.

By Johannes Senex, R.S.S., Londini.

After the death of J. Senex in 1749, his globes were sold by his widow, as appears from 'A Catalogue of Globes, Maps etc. made by the late John Senex F.R.S. and continued to be sold by his Widow, *Mary Senex*, at the *Globe*, where may be had all Maps and Globes, etc., as in Mr. Senex's Lifetime'.[1]

List follows (8 pp.) with a note.

His Globes may be known from any others, by having Bayer's Letter of Reference inserted on the Celestial, and the Rhumb Lines beautifully delineated on the Terrestrial; and if required, the Celestial, of 17 Inches, may be made so as to adjust the Intersection of the Equinoctial and Ecliptic to any Time, past or to come. Price 4*l.* 7*s.*

[1] Stevenson (*Globes*, 1921) quotes three globes attributed to Senex which are dated as late as 1793 and had been brought up to date by Dudley Adams.

NO. 144. ORRERY BY THOMAS WRIGHT, 1731

Christ Church

112–13. Pair of Globes. 1757.

Diameter 2 feet 2 inches. Oriel College.

A new and most correct Globe of the Earth.

By J. Senex, F.R.S.

Sold by Martin, Fleet St., 1757.

114–15. Terrestrial and Celestial Globes. c. 1750.

Diameter 17 inches. New College.

Under hexagonal glass shades.

By G. Adams in vico Fleet St.

With a dedicatory inscription to George III in Latin. The track of Anson's voyage (Report published in 1749) is marked.

116–17. Terrestrial and Celestial Globes. c. 1753.

Diameter 12 inches. Bodleian Library.

By Geo. Adams of Tycho Brahe's Head, Fleet Street.

To his most sacred Majesty
George the Third
This new Celestial Globe
containing all ye southern Constellations
lately observed at the Cape of Good Hope and
all the stars in Flamsteed's British Catalogue
is most humbly inscribed By his Majesty's
most dutifull and obliged subject and servant
G. Adams.

Sold by G. Adams, Mathematical Instrument Maker to ye King Fleet St. London. At Tycho Brahe's Head.

The Meridian on this globe was drawn for the year 1753.

118–19. Pair of 18-inch Globes. c. 1760.

University College.

Presented in 1766 by Francis Garbett.

The globes are accompanied by two 8-inch compasses with printed dials, with maker's name.

'Made by GEO. ADAMS in Fleet Street, LONDON.'

G. Adams was of 60 Fleet Street in 1763 (*London Directory*). He was a maker of mathematical instru-

ments and optician to George III, and was succeeded by his sons George (1750-95) and Dudley who in 1810 issued the thirtieth edition of his father's *Treatise describing and explaining the construction and the use of new celestial and terrestrial globes, designed to illustrate in the most easy manner the phenomena of the earth and heavens.* London 1766.

Pair of 9-inch Globes. **1782.**

Northwick Park, Worcester.

By [G.] Wright.

Wright's
New Improved
Celestial Globe
on which the stars are
Carefully laid down by
Dr. Halley, Dr. Bradley Etc.
Sold by P. & J. Dollond
LONDON.

Wright's
New Improved
Terrestrial Globe
on which the Latitudes &
Longitudes of Places are
Carefully laid down
with all the New Discoveries
Made by the late Capt. COOK [1]
and other eminent
NAVIGATORS
to the present Time.

With an additional label:—
Sold by
P. and J. Dollond, London.

Near the S. Pole is the further inscription:—
Published by G. Wright and W. Bardin, Jan. 1, 1782.[2]

120-1. Terrestrial and Celestial Globes. **1798.**

Wadham College.

By D[udley] Adams, Fleet Street.

122. Celestial Globe. **? 1800.**

Diameter 1 foot 6 inches. University Observatory.

By W. Bardin.

Dedicated to Nevil Maskelyne, D.D., F.R.S., who was Astronomer Royal, *c.* 1766–1811.

Manufactured by S. S. Edkins, son-in-law and successor to W. Bardin, Salisbury Square, London.

[1] 1779.
[2] G. Wright was the author of *The description and Use of both the Globes, the Armillary Sphere, and Orrery exemplified in a variety of problems in Astronomy.* London 1783.

123–4. Pair of Globes. 1799–1800.
Diameter *c.* 1 ft. 6 in.

The Library, Trinity College.[1]

By Cary.

Cary's
New
Terrestrial Globe
exhibiting
The Tracks and Discoveries
made by
Captain Cook
also those of Captain Vancouver
on the
North West Coast of America
and M. de la Perouse on the
Coast of Tartary
together
with every other improvement
collected from
various Navigators to the
present time.
London.

Cary's
New and Improved
Celestial Globe
on which
Is carefully laid down, the whole
of the
Stars and Nebulae
contained in the Astronomical
Catalogue of the
Revd. Mr. Wollaston F.R.S.
Compiled from the Authorities of
Flamsteed, de la Caille, Hevelius,
Mayer, Bradley, Herschel,
Maskelyne & Co.
With an extensive number from
the works of Miss Herschel.
The whole adapted to the Year
1800 and the Limits of each
Constellation determined
by a Boundary Line.
London.

Made and sold by J. & W. Cary, No. 181 Strand, March 1, 1799.

125. Celestial Globe. 1799 'for 1800'.
Diameter 20 inches. Radcliffe Observatory.
By William Cary.

126. Terrestrial Globe. 1815.
Diameter 20 inches. Radcliffe Observatory.
By William Cary.

127–8. Pair of similar Globes. 1799 and 1815.
Worcester College.

By William Cary.

129. Celestial Globe. March 1799 adapted for 1800.

130. New Terrestrial Globe.
London 1815, with additions and corrections to 1822.
Magdalen College.
By William Cary, with the Travels of Captain Cook.

[1] The entry in the *Benefactors Book* of Trinity College recording a gift of £20 from Nathanael Geering is embellished with a paint-

William Cary (1759–1825) was at first associated with Ramsden and made many astronomical instruments. He set up in business for himself in the year 1790.

131. Terraqueous Globe. 1820–30.

Diameter 3 feet. Jesus College.

By John Addison.

The
TERRAQUEOUS GLOBE
Exhibiting
the present state of the known
WORLD.
Published under the immediate Patronage of
& dedicated by Permission to
HIS MOST GRACIOUS MAJESTY GEORGE IV
By
John Addison
LONDON.
Manufactured & sold by G. & J. Cary, No. 86 St. James Street,
LONDON.

132. Celestial Globe.

In possession of R. Gunther.

THE
NEW TWELVE INCH
BRITISH CELESTIAL GLOBE
Containing the exact positions *of more than* 3800 FIXD STARS, *Nebulae, Planetary Nebulae etc. according to the* Latest Discoveries *and* Observations *of Dr. Maskelyne, Dr. Herschell and other eminent* Astronomers *and corrected to the present period.*
Sold by J. Souter
73
St. Pauls Church Yard.

ing of a globe of the period of the latter half of the seventeenth century. I do not know whether this had reference to the object of the benefaction or not. The date of the entry is 1756, late for the style of globe represented and early for the above-described Cary globes.

133. Concave Celestial Hemispheres in cardboard. 1829.

Radcliffe Observatory.

By I. C. Böhme.

This celestial 'globe' was probably suggested by the Astroscope, an instrument 'composed of two cones on whose surface the constellations with their stars are delineated' (Chambers, *Cycl. Supp.* 1753). It was the invention of Wil. Schukhard, Professor of Mathematics at Tübingen in 1698.

134. 12-inch Terrestrial Globe, with Land in Relief.

Radcliffe Observatory.

By D. Reiner, Berlin.

Lunar and Planetary Globes

Wren's Globe of the Moon. 1661.

This, the first of its kind, was made in Oxford by Wren, but is not now extant.

To Dr. Wren *at* All-Souls *College in* Oxford.

Sir,

I am commanded by the Royal Society to acquaint you, that his Majesty expects you should prosecute your Design of making the Representation of the Lunar Globe in *Solido*. . .

I am, Sir, *etc.* Hen. Powle.

The globe of the Moon in the solid was accurately finished on the basis of a globe procured from Moxon, and was presented to his Majesty at Whitehall, fixed on a pedestal of Lignum vitae, curiously turned, with this inscription, and a scale of miles.

CAROLO SECVNDO
M. BR. FR. ET HIB. R.
CVIVS AMPLITVDINI QVIA VNVS NON
SVFFICIT
NOVVM HVNC ORBEM SELENOSPHAERIO
EXPRESSVM
D.D.D.
CHR. WREN.

The globe was placed among the curiosities of the King's cabinet. It represented not only the spots and various degrees of whiteness upon the surface of the moon, 'but the hills, eminences and cavities of it moulded

in solid work, which if turned to the light shewed all the phases of the Moon, with the several appearances that arise from the shadows of the hills and vales'.

135. Selenographia. Russel's Lunar Globe. 1797.
Diameter 1 ft. Radcliffe Observatory.

A globe representing the visible surface of the Moon constructed from triangles measured with a micrometer and accurately drawn and engraved from a long series of Astronomical Observations by J. Russel, R.A. Part of Selenographia published by the Author, Newman St., London. June 14, 1797.

Bianchini's Globe, representing the Planet Venus.
No. 70, Royal Society.
Pres. by Sir Thomas Dereham.

Astronomical Globes and Spheres

A fine series of astronomical globes may be seen in the Conservatoire des Arts et Métiers in Paris. Beginning with two superb examples of 1580 and 1588, both with clock movements, by Jost Burgi and Johan Reinhold respectively, there are dated examples of the work of Nollet 1730, Desnos 1757, Fortin 1769, J. Hardy 1787, Delamarche 1785, and Messier 1800.

Ptolemaic Planetarium within Armillary Sphere.
1602.
Vernon Watney Esq., Cornbury Park.

FRANC^S LAGSTINVS FACIEBAT MDCII VOLENTEM VOLVVNT.

An interesting model mounted on a bronze statue, with the 9 spheres represented by revolving circles, all of which are inscribed with their names and appropriate information.

136. Globe. Gilt brass on Stand. c. 1700.
Diameter $5\frac{1}{4}$ inches. Orrery coll. 10.
I. Rowley fecit.

Engraved with 'Artick Pole, Tropick Cancer, Aequinoctial, Ecliptic, Tropick Capricorn, Antarctick Pole, and Merid(ian)' Circles appropriately graduated and numbered in degrees and hours. The horizontal rim of the stand is also divided into degrees. Altitudes can be measured by a movable arc graduated from 0° to 90°.

GLOBES AND PLANETARIA BY ROWLEY, C. 1700

Orrery collection at Christ Church

137. $2\frac{1}{2}$-inch Globe set to turn in a brass meridian divided in degrees. **c. 1700.**

Orrery coll. 24.

138. $1\frac{1}{2}$-inch Globe of Ivory on a Stand. **c. 1700.**

Orrery coll. 25.

The base of the stand is inscribed in ink 'a planet set down any were'—probably meaning on an Orrery. Certain small brass pegs projecting from the equator and tropics, &c., were probably taken to represent men standing on various latitudes to show how their shadows would lengthen as their distance from the equator increased.[1]

139–40. A pair of wire Planetaria. **c. 1700.**

Diameter $15\frac{3}{4}$ inches. Orrery coll. 1.

1. Ptolemaic Planetarium.

Around a central Earth mounted on an oblique axis ($23\frac{1}{2}°$) are the movable orbits of the moon, sun, and planets indicated by symbols in order ☽ ♁ ☿ ☉ ♂ ♃ ♄. An external band divided into the 12 zodiacal signs (named) completes the instrument.

2. Copernican Planetarium.

Around a central Sun are the movable orbits of the planets indicated by symbols in order ☿, ♁, Earth on oblique axis, and ☽ ♂ ♃ ♄. The rotation of the earth on its axis is effected by a train of 3 wheels. An external silvered band divided into the 12 zodiacal signs (named) completes the instrument.

Rowley appears to have made these planetary models in exact illustration of the diagrams printed in 1670 by J. C. Sturm in the 'Iconismus primus' (= plate 1) of his *Scientia cosmica*. There, with various comparative diagrams of planetary theories, he gives the *Systema copernicanum*, fig. 20, and the *Systema Ptolemai Platonicum*, fig. 21.

An early demonstration (before 1550) of the Copernican System was given by Girolamo Fracastoro, who

[1] For the use of such pegs cf. Desaguliers' *Expt. Philosophy*, 2nd edit., p. 458; and for an earlier instance of a similar pictorial argument see the *Sphaerae Tractatus* of 1531, f. 16.

showed 'uno instrumento fatto sopra un moto dè cieli trovato nuovo'.[1]

Future generations may be surprised that Planetaria constructed according to the Ptolemaic theory should have continued to be in demand in the eighteenth century, nearly two hundred years after Copernicus had preached the true gospel of the solar system. But the world and the church never hasten to leave their castle of ignorance, when they have once securely barred themselves within. The Ptolemaic system was so essential to the heavens in declaring the glory of God and to the firmament in showing his handiwork, that it was not until one hundred years ago (1822) that the works of Copernicus were removed from the *Index Expurgatorius* of the infallible church.

141–2. A pair of Planetaria within Armillary Spheres. **c. 1700.**

Diameter 14 inches. Orrery coll. 7.

On Brass Stands: Scales silvered.

1. Ptolemaic. 'John Rowley Londini fecit.'

The Armillary Sphere consists of the usual circles engraved and graduated on bands of brass, already described in the 5-inch Sphere p. 264.

Five stars, *Aldebaran*, *Cor Leonis*, *Spik Virginis*, *South Libra*, *Cor Scorpio*, are marked on the ecliptic band.

Altitudes can be measured by a scale on a movable arc.

At the centre of the sphere the Earth is surrounded by the orbits of the sun, moon, and planets in the Ptolemaic order. All are mounted upon eccentric axes to illustrate their apparent movements. The polar axis of the earth projects at the top of the sphere and carries a pointer which moves round a small circle of hours, I–XII, I–XII.

The stand heavily weighted with lead can be levelled with three levelling screws and roughly orientated by a small compass in a box on the lower side of the rim. The silvered upper surface of the rim is divided into circles (1) of degrees numbered 0° to 90° from the first

[1] Cf. Fiorini, *Fracastoro* in *Rivista geografica italiana*, 1900, pp. 438–45. Copernicus *De revolutionibus orbium coelestium* was published in 1543.

NO. 141. PTOLEMAIC PLANETARIUM BY ROWLEY, C. 1700

Orrery collection at Christ Church

NO. 143. SILVER PLANETARIUM AND CASKET BY ROWLEY, C. 1700

Orrery collection at Christ Church

points of Aries, Cancer, and Capricorn, (2) of Signs of the Zodiac with pictures and symbols, (3) of degrees of the Signs, (4) of days of the months ($9\frac{1}{2}$ of March corresponding to the first point of Aries), and (5) points of the compass. A small bearing wheel supports the outer ring of the armillary sphere.

2. Copernican. 'I. Rowley fecit.'

The second instrument is almost a replica of the first, except so far as it shows signs of being a trifle less finished, for example, the zodiac stars are omitted and the maker's name is abbreviated. But in the centre the simple Copernican System takes the place of the Ptolemaic eccentricities. The turning of the earth upon its axis is effected by a train of five cogwheels, and the moon is carried round at the same rate.

143. Miniature Copernican Planetarium within an Armillary Sphere. c. 1700.

Silver.

Orrery coll. 11.

'I. Rowley fecit.'

This exquisitely finished working model of the second of Rowley's Planetaria, above mentioned, is probably one of the finest small astronomical models ever made in England. It is supported on an ebony base by a tripod, between the legs of which is a magnetic compass for orientation. This 'very childish toy', as Herschel would have called it, is enclosed in a turned brass-bound casket of lignum vitae.

ORRERY

An **Orrery** is a machine for representing by wheelwork the various motions of the heavenly bodies. This machine differs from a Planetarium in that it exhibits the diurnal as well as the annual motions of the earth, the revolution of our moon, and sometimes the rotation of the sun and of certain planets on their axes. The larger instruments, called 'Grand Orreries', exhibit, moreover, the motions of the secondary planets, but more particularly those of Jupiter.

By the Orrery it is possible to represent all the vicissitudes of summer and winter, of spring and autumn, of

day and night, the risings, settings, and culminating of the heavenly bodies, together with their constantly varying altitudes and azimuths, their right ascensions, declinations, and amplitudes, their conjunctions and oppositions, their transits and occultations or eclipses. The orrery is therefore a machine of the first importance as a means of education in planetary motions.

The special connexion of the cabinet of philosophical instruments at CHRIST CHURCH with the LORD ORRERY in whose honour this elaborate form of planetarium has received its name, and the acquisition by Christ Church of the orrery by Thomas Wright, gives this complicated piece of mechanism a special local interest.

The manner in which the instrument came by its name was due to several coincidences. Before the year 1715[1] an instrument was contrived and made by GEORGE GRAHAM, which represented at the same time both the annual and diurnal motions of the earth, and also the synodic period of the moon; these motions had never before been exhibited together by any mechanical contrivance, at least in England. The instrument was put into the hands of a workman to be packed and sent to Prince Eugene. Whether this workman was Rowley, or some other person employed by him, does not appear; but it is said that he copied the model put into his hands, and from it Rowley made a machine for the Earl of Orrery, with additions of his own invention.

Sir Richard Steele, who knew nothing of Graham's instrument, wishing to do honour to the inventor, as he thought, of such an ingenious and complicated piece of mechanism, named it an orrery, and attributed to Rowley the honour which was due to Graham.[2]

This at any rate is Dr. Desaguliers' account of the origin of the orrery, from which it may be inferred that Graham invented the parts of the machine which relate to the earth and moon, and that Rowley added those which produce the motions of the other planets. The details of the wheelwork of the two portions have been

[1] According to the *N.E.D.*, Orreries were invented by Geo. Graham *c.* 1700 and were made by J. Rowley, but I have not found any authority for so early a date as 1700. Certainly the year of the invention cannot have been later than 1710, but it may have been 1705.

[2] Steele, *Englishman*, No. 11, 1713.

described from an orrery made from Rowley's plan by order of the East India Company.[1]

The fame of the orrery and its maker was not long in spreading. In 1719 J. H., a Fellow of the Royal Society, wrote a little brochure of *Astronomical Dialogues Between a Gentleman and a Lady wherein the Doctrine of the Sphere . . . are explained in a pleasant, easy and familiar Way. With a description of the famous instrument called the Orrery.* London, 1719.

The gentleman describes an orrery 'which I think was made by M. Rowly, the famous Instrument maker, and Master of Mechanicks to the king; and whom I find you have always recommended in your books as the best Workman of his Profession'.

The book includes an engraving of the instrument and a poem in imitation of Claudian, *Epigr.* xiii, *In Sphaeram Archimedis*:

When lately Jove the *Orrery* survey'd
He smiling thus to Gods in Council said,
How shall we stint presuming Mortals Pow'r?

. . . . . .

But his Machine by one fixt Pow'r and Weight
Mov'd, and was govern'd, as we are by Fate
While the bold Rowley in his Orrery
Keeps his first Pow'r, just like his Genius free
He knows the secret springs; and can impart
Laws to the whole, and to each single part
His daring Hand, or brings or hinders Fate,
Makes *Mercury* fly, or Saturn walk in State.

. . . . . .

Shall I to please you take off Rowley too?
O! no! all cried, the glorious Artist spare;
Transplant him rather, and make him a Star.

The **original orrery** made by Rowley did not come to Christ Church with Lord Orrery's other scientific apparatus, but remained in the Orrery family. It was publicly exhibited in 1876 with the Loan Collection at the S. Kensington Museum where a photograph of it is now on view.

According to Stone the case was 12-sided, constructed of ebony with silver pilasters at the corners and with 12 silver signs of the zodiac in the twelve panels.

[1] Rees' *Cyclopaedia*, Art. *Orrery and Planetary Numbers.*

144. Orrery. 1731.

Christ Church.

Made by THO. WRIGHT (*Mathematical Instrum*[t] *Maker to His* MAJESTY GEORGE y[e] II[d]) *in Fleet street LONDON.*

Circle 3 feet in diameter, 1 foot high.

When this orrery was repaired by Mr. Henry Minn about 1912, a photograph was taken, and a working drawing made of its various trains of wheels.

In 1733 Wright made a magnificent Grand Orrery for the Royal Observatory at Richmond. Its cost was estimated at about £1500. His success as a maker of orreries is thus described by B. Cole, his successor in business who hoped to inherit his mantle:

'The great encouragement Mr. Wright has had for many years past in making large Orreries, with the Motions of all the Planets and Satellites, and the true Motion of Saturn's Ring has made him so ready and perfect, that Gentlemen may depend on having them made reasonable and sound, not liable to be out of order.

As may be seen from one he made for Mr. Watt's Academy in Tower Street.

Another for his Majesty at Kensington.

Another for the New Royal Academy at Portsmouth.

Another for his Grace the Duke of Argyle (the late Lord Ila).

And several other large ones for Noblemen and Gentlemen.

The above are now made . . . by B. Cole, Servant to Mr. Wright[1] at the Time of the above being made, and Successor to him in the same Trade and Business.' Jos. Harris, *Descr. and Use of Globes and the Orrery*, 1763.

B. Cole was succeeded by John Troughton, Edward Troughton, and by Troughton and Simms, now of 138 Fleet Street, the same house in which Wright lived, though it was numbered 136 in his day.

[1] This Thomas Wright must not be confused with T. Wright of Byer's Green, born in 1711, of whom an amusing sketch, illustrated by a portrait, appeared in the *Gentleman's Magazine* for January and February 1793. After an adventurous youth and an unsuccessful love-affair, he learnt the art of making instruments under Messrs. Heath and Sisson, and while the other Thomas Wright

NO. 145. ORRERY BY B. COLE, C. 1750

Queen's College

145. Orrery. c. 1750.

Queen's College.

Made by B. Cole and Son
at the
ORRERY
Fleet St.
London:

Cole succeeded T. Wright *c.* 1750.

This instrument, though built on the same plan, shows an advance on the Orrery at Christ Church by including the orbit of Mars. It was fitted with 'A New and Correct Globe of the Earth' by I. Senex, F.R.S.

Dedicatory inscription and Arms and Motto of Queen's College on two circular plates.

Edwyn Franc Stanhope
Gulielmus Gyse
Edmondus Thomas
Georgius Mowbray
Oldfield Bowles
Ricardus Symonds
Superioris Ordinis Commensales
D.D.
An. Dom. 1763.

Orrery.

No. 65, Royal Soc.

By Cole (explanatory of eclipses).

147. Grand Orrery. c. 1770.

All Souls College.

The clock bears the names of Heath and Wing.

A Planetarium by Thomas Heath is in the Conservatoire des Arts et Métiers in Paris, where examples by Huygens and Arsandeaux may also be consulted.

In 1771 Benjamin Martin published a shilling pamphlet,

was making Orreries, designed almanacks and calculated eclipses, and afterwards gave instruction in astronomy to 'great personages' of both sexes, in whose country-houses he used to stay for prolonged periods. He had a *villula* at Byer's Green, the staircase of which was ornamented with a large scheme of the universe, the sun, moon, and systems of the planets and comets. *Gent. Mag.*, March 1793.

The description and use of an Orrery of a new construction . . . to which is subjoin'd a mathematical theory for calculating the WHEEL-WORK *to the greatest degree of exactness.* At the end is his *Advertisement* stating the prices of six types of Orreries, the fifth being the Orrery compleat, £105; and the sixth, 'with all the additional machinery', £157 10 0.

APPARATUS TO DEMONSTRATE THE ROTATION OF THE EARTH

148. Foucault's Pendulum. c. 1850–60.

Formerly suspended from the NW. side of the centre of the Dome of the Radcliffe Camera.

When the pendulum was set swinging a pencil attached to the bob traced lines on a sheet of paper spread out on a table which turned with the Earth, while the direction in space of the swing of the pendulum remained unchanged. The wire is still in situ (1923), but the table and pendulum-bob were removed when the room was lent as a Reading Room for the Bodleian Library in 1860.

NOCTURNALS OR NIGHT DIALS

Synonyms:

Instrumentum syderale. Gemma Phrysius, 1539.

Instrument general for the houres of the nyght. Eden, 1561.

The Rectifier of the North Star. Blundeville, ? 1597.

Nocturnal. Capt. Smith, *Seaman's Grammar*, 1627.

Horometer.

G. Fournier, *Hydrographie*, x, c. 20, and A. Schück, 'Das Horometer', *Mitt. Geogr. Ges. München*, i, 1905, p. 269, both give illustrated descriptions of the nocturnal. (Ravenstein, *Behaim.*)

The hour of the night was usually determined by observation of the relative position of certain easily recognizable stars. LEONARD DIGGES[1] in 1553 recommended Aldebaran and Abramech for the purpose, and printed instructions for ascertaining the hour.

[1] *Prognostication*, 1555 edit., f. G.

NO. 147. GRAND ORRERY SEEN FROM ABOVE

All Souls College

NO. 147. GRAND ORRERY BY HEATH AND WING, C. 1770

All Souls College

NO. 147. GRAND ORRERY BY HEATH AND WING, C. 1770

All Souls College

The Nocturnal was a handy means of doing the same thing readily with instrumental help from observations of the position of some particular star or stars, for which the instrument was constructed, relatively to the Pole Star. The stars usually selected for northern latitudes being the Pointers of the Great Bear, or the 'Bright' star of the Little Bear (γ Ursae minoris); and these were the stars recommended by Richard Eden in *The Arte of Navigation* translated from the Spanish of Martin Cortes, 1561.

The Nocturnal can be traced back to 1533 when it was described in Seb. Munster's *Horologiographia* and to the Instrumentum Syderale described in Apian, *Cosmographia*, per Gemmam Phrysium apud Louanienses, 1539. And even in the preceding century we find figures of instruments that would serve the purpose as, for instance, a figure in MS. Digby 48, of the date 1433–62.

An early form of nocturnal[1] used by Dutch sailors was made by suspending a small ring in the centre of a hoop by strings. The periphery of the hoop was marked by 24 pins. About 1600, T. Hariot wrote his description *Of taking the altitude of the N. pole by the North Starre, & a new rule of the guards, made & calculated according to precise and late observations.* MS. Add. 6788.

There are excellent drawings of the Nocturnal and of the Cross-staff after Metius in Colume, *Fierie Sea Colume*, 1640.

The instrument usually consists of two circular plates of different diameters capable of being rotated on a perforated axis. Moving on the same axis is also an index rule, sufficiently long to project beyond the circumference of the larger plate.

The large plate is marked with two circles, one of hours I–XII, I–XII, the other of days of the year, and is attached to a handle in such a position that the mid-line of the handle traverses the division for the day on which the star to be observed and the sun have the same right ascension; e.g. if the nocturnal be made for the 'Pointers', the handle must be in line with Sept. 1; if for the γ Ursae minoris, the handle must be in line with Nov. 8th.

[1] Robert Norman, *The Safeguard of Sailors or Great Rutter translated out of the Dutch*, London, 1584.

The smaller or hour-plate is divided into $29\frac{1}{2}$ parts for the days of the lunar month, and has an inner hour circle similar to that of the larger plate. In many instruments it is provided with raised knob-like bosses or with marginal teeth, to allow of the hours being counted at night without a light, while a tooth longer than the others served to indicate 12 o'clock. In some instruments there is the long tooth only.

The Use of the Instrument. Turn the upper circular plate till the longest tooth whereat is marked 12 be against the day of the month on the under plate; then bringing the instrument near your Eye, hold it up by the handle, so that it leans neither to the right or left, with its plane as near parallel to the equinoctial as you can; and looking at the Pole-star thro the hole in the centre of the instrument, turn the index about, till by the edge coming from the centre, you can see the bright star or Guard of the Little Bear (if the instrument be adapted for that star) and that tooth of the upper Circle that is under the edge of the index, is at the hour of the night upon the edge of the Hour-circle; which may be known without a light, by accounting the teeth from the longest, which is for the hour of 12.[1]

We have seen the following dated examples[2] of the instrument:

Nocturnal and Quadrant. 1543.

Gilt Metal: diameter $5\frac{3}{16}$ inches. S. Kensington Museum.

Inscribed 'Casper Vopel mathema faciebat Coloniae'.

Nocturnal. 1554.

Gilt brass. Diameter 2 inches. Bodleian Library.

This beautifully finished miniature nocturnal is included in R. P.'s metal book of instruments and tables described on p. 279.

Nocturnal. 1655.

British Museum.

Inscribed 'B.B.' (= Both Bears).

[1] Stone's Bion, *Mathematical Instruments*, p. 253.

[2] Mr. Evans has noted several early examples, one by Le Clerc of Paris 1527, others by Michael Coignet of Antwerp 1589 and 1598. He has one by M. J. Stoltrup in his own collection, and many others are included among his Portable Dials.

Foster's Nocturnal. 1671.

Engraving by Jonas Moore.

Described in an 8-page pamphlet entitled *The Description and Use of the Nocturnal*: by Mr. Samuel Foster. *With the Addition of a Ruler, shewing the Measures of Inches and other parts of most Countries, compared with our English ones; Being useful for all Merchants and Tradesmen.* To which is added *Additions to the Instrument, in* Brass *made by Mr.* R. Aug. 1st 1684. Mr. R. was an Ingenious Gentleman of the French Nation.

This pamphlet appears to have been sold by Walter Hayes, as an appendix to J. Twysden's *Use of the General Planisphere called the Analemma,* 1685.

Peripole. 1671.

L. Evans collection.

By Loysel.

Nocturnal. 1713.

S. Kensington Museum.

By 'Edw. Tyzack' of Bristol.
Marked 'Both Bears'.

Nocturnal. 1723.

British Museum.

Marked 'Iohn Johnson'.

Nocturnal. n. d.

S. Kensington Museum.

Marked 'BOTH BEARS' and stamped with stars and a rose.

The two Oxford examples most resemble the latter instrument.

149. Nocturnal. 18th cent.

University Observatory.

Boxwood, marked with rose and fleur-de-lys stamps. The rose stamps are identical with those put by Joseph Stutchbury upon his Excise slide-rules, and may also be seen upon an Edm. Culpeper (1666–1738) Backstaff in the Pitt-Rivers Collection.

150. Nocturnal. **18th cent.**

Radcliffe Observatory.

Boxwood. A very similar instrument—of the type described by Sir Jonas Moore, *A New System of Mathematics*, 1681.

No. 150. Nocturnal.

ALMANACKS AND CALENDARS

Although neither Almanacks nor Calendars come within the scope of a work on Scientific Instruments, yet it is convenient to take note of a few that are combined with calculating machines or other instruments, or are made of materials other than those usual in books.

In a definition of the terms Almanack and Calendar written in the year 1267, a clear distinction is drawn between them.

'Tabulae vocantur *Almanach* vel Tallignum, in quibus . . . homo posset inspicere omnia ea quae in caelo sunt omni die, sicut nos in *calendario* inspicimus omnia festa sanctorum.'

The early mediaeval almanacks were doubtless based on the astronomical tables of Toledo constructed by Arzachel about 1080.

The almanacks known to ROGER BACON and CHAUCER were permanent tables of the apparent motions and positions of the sun, moon, and (?) planets, whence astronomical data for past or future years could be calculated. Chaucer used

'A table of the verray Moeuying of the Mone from howre to howre, every day and in every signe after thin Almenak.'[1]

The Astronomical Tables constructed by Members of Merton College for the latitude of Oxford have already been described. They were extensively used in the fifteenth century for the construction of the standard Almanacks; and Rules for the purpose may be consulted in MS. Digby 48, where there are *Regulae 'ad faciendum unum Almanak per tabulas Rede episcopi Cisestrensis'*. These calculations of the places of the sun and moon, or ephemerides, 'quas vulgo vocant almanach', as Regiomontanus termed them in 1475, were prepared for definite periods, such as 10 or 30 years. And the majority being based on the latitude of Oxford, our University became known far and wide as the centre of Astronomical Science in Britain.

The reputation of Oxford Astronomy lasted into the sixteenth century, as is shown by W. de Worde's *Almanacke for xii yere* printed in 1508.

[1] Chaucer, *Astrolabe*, 1391.

'This Almanacke and table shall endure xii yere and is called after the latytude of Oxenforde and it is taken out of the grete ephymerides or almanacke of xxx yere.'

Annual almanacks, sometimes combined with the ecclesiastical calendar, made their appearance in the sixteenth century and were printed; but such printed almanacks are said not to have come into general use in England until the middle of the sixteenth century. They were no doubt popularized by the inclusion of astrological and weather predictions, for these appeared before the end of the sixteenth century, and most of the best mathematicians of the time were employed in constructing them. Before the end of the seventeenth century almanack-makers began to form a distinct body, and though, as Halliwell remarks, they often styled themselves 'students in the artes mathematicall', very few of them were at all celebrated for their knowledge of the pure sciences.

151. Mexican Calendar Stone.

Presented by Miss S. Bullock, London.

No. 405 a. Ashmolean Museum.

A model.

The original stone, formed of basalt, was upwards of 36 feet in circumference, weighing more than 5 tons, and known to the Indians by the name of Montezuma's watch. In the centre of this immense tablet is the figure of the sun, the rays in the direction of the cardinal points; round the head, the seasons are represented in hieroglyphics, and in the next circle, the name of the 18 Mexican months of 20 days, thus making the calculation of time nearly the same as ours.

152. Annulus of John of Northampton. 1328.

MS. Bodl. 68, S. C. 2142, Bodleian Library.

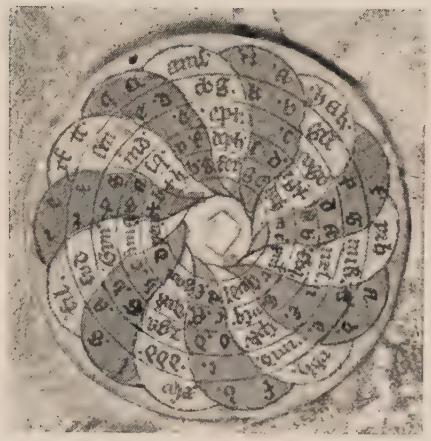
A pretty invention of Johannes de Northampton in 1328 for the computation of the date of Easter.

Calendar on Pendent Sundial. 1537.

St. John's College.

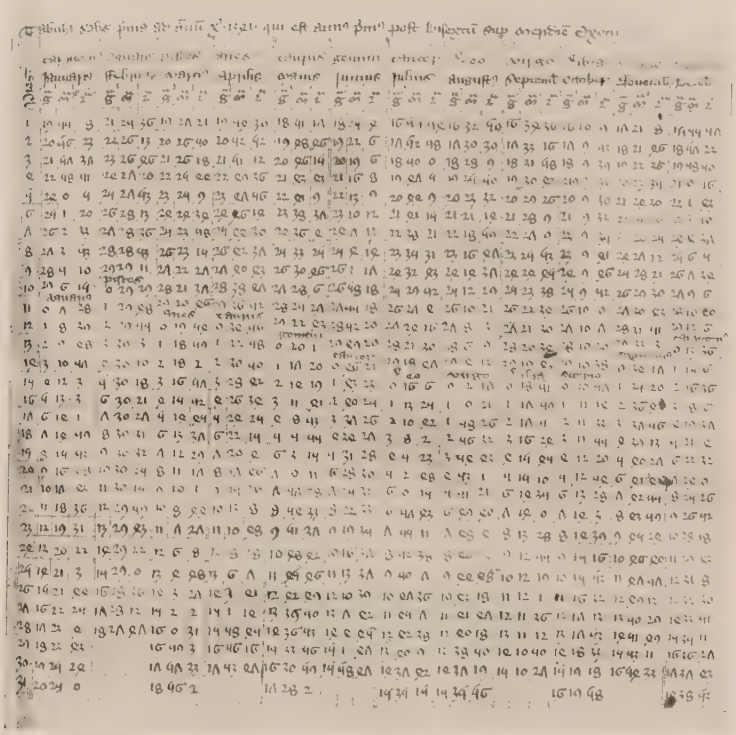
Inscribed: 'Roger Brechte 1537.'

This Calendar is printed in full on page 138 with the description of the instrument.



NO. 152. ANNULUS OF JOHN OF NORTHAMPTON

MS. Digby 98

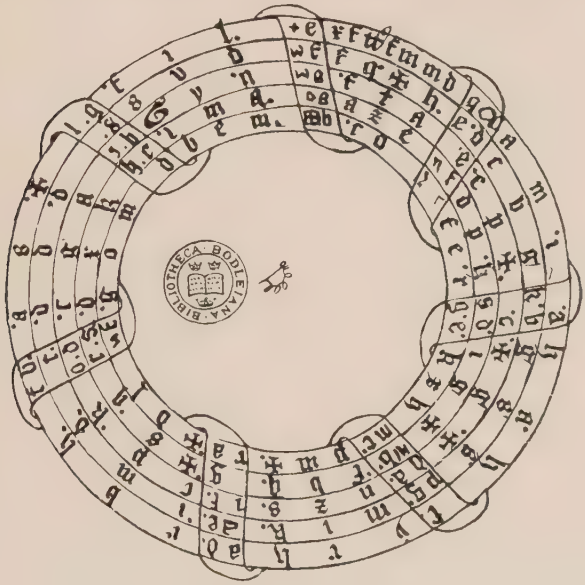


SIMON BREDON'S COPY OF AN OXFORD ALMANACK FOR 1341

MS. Digby 178, f. 12v

153. Annulus of John of Northampton. ? 1348.
MS. Digby 98, f. 41*v.

Contrived on a smaller scale than the other. The bands are coloured yellow and white. See fig. facing p. 278.



152. JOHN OF NORTHAMPTON'S ANNULUS, 1328.
MS. Bodl. 68.

49. Pocket Dial, Almanack, Compass, and Tidetables.
1554.

Maker's initials **V C** Bodleian Library.

See p. 127.

In the inside are the following tables and instruments, all engraved on gilt brass. Several correspond exactly with the tables in Leonard Digges, *Prognostication*, 1555.

Inside front cover.

1. A fixed circular plate with a neat diagram of the constellations of 'VRSA NINOR' and 'VRSA MAIOR' and of the position of the 'POLVS' relatively to the

'STELA POLARIS'. Evidently for use with the Nocturnal. See p. 274.

2. Table of latitudes of British towns.

DOVER	51.30	NOTINGAM	53
CANTERBVRE	52	LEISETER	52
LONDON	52.30	HERTFORD	52.50
NORWEGE	53	CESTRIA	51.50
HAMTON	54	COLCESTI	51
EBORACI	54.50	OXONIA	51.50
NEVCASTEL	55	BARWIKE	56.50
EDEBOROV	57	CARLELE	54
			55

3. Nocturnal, 360 degrees and zodiac circles, surrounding a movable disk marked 1–9 and 12-3 with an index at 12.
4. A small leaf with a revolving disk representing an armillary sphere, backed by
5. A clinometer or quadrant.

This leaf was probably also used to carry a wind vane, now missing, and as

6. A bracket to support a leaf carrying a string gnomon to the centre of the sundial, No. 8.
7. Volvelle showing phases of the moon within hour circles and a circle divided into 29½ parts.
8. Compass dial engraved within the plate of a horizontal sundial. A similar compass dial is figured and described in Digges, *Prognostication*, f. 3. 'The good Mariner may long for the use of this instrument: it serveth marvelously his tourne.'

The *Quadratum Nauticum* of Gemma Frisius was a similar compass dial.[1]

9. Table showing

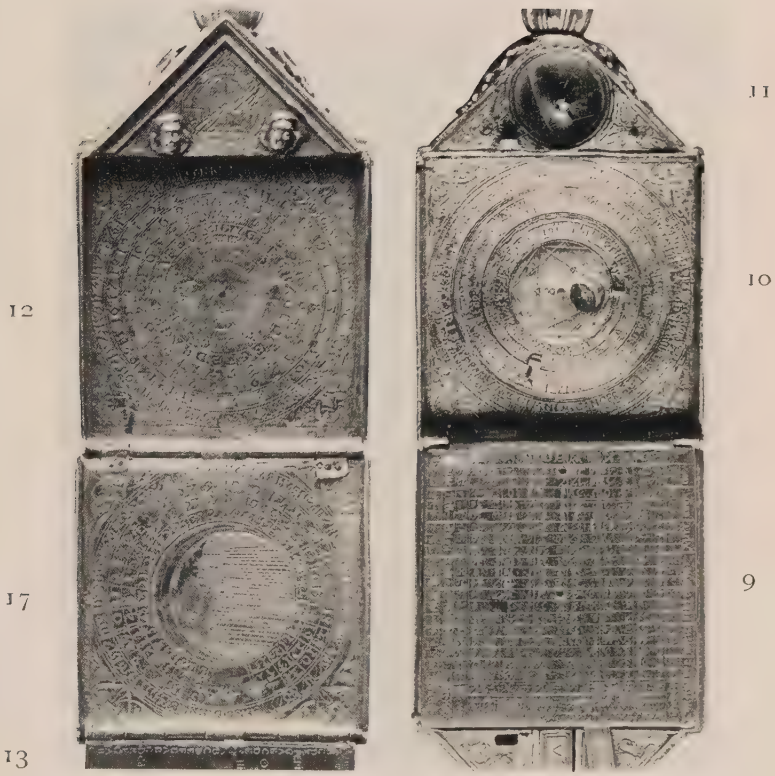
Break of the day	Sunne rysinge	Length of the d	Legth of the nigh	Sunne setting	Twy lyghte

for the 1st, 10th, and 20th Dayes of every Moneth.

Cf. a similar table in Digges, *Prognostication* (1555), f. 24^{v} in 1564 edit. Its use is there explained.

10. Circular dial with two rotating circles.
    a. Inner circle showing phases of the moon, engraved

[1] Blundeville, 1636, p. 770.



NO. 49. V. C.'S POCKET DIAL, 1554

Bodleian Library

with the signs of the aspects,[1] the concentric triangle, square and pentagon.

b. Circle of 31 days of month, ornamented with a serpent facing ☊ (head of dragon).

c. Circle of months divided into days.

d. Circle of zodiac signs.

Cf. Instrumentum solis. Apian, *Cosmogr.* f. 9ᵛ, 1551 edit.

11. A small magnetic Compass in the pediment.

12. Circular Table round a sun for the years 1554–79 giving the

AVREVS NVMERVS
INTARVAL
LVM
SONDAY
LETER

Numbers for a similar series of years 1554–81 are given in Digges, l. c., f. 20ᵛ.

Inside the back cover.

A book of 4 leaves of gilt brass, engraved on both sides with Tables 13 to 18.

13. A 'generall Kalendar', on pages 1-3, stating the golden letters, saint's days, and dates of the sun's entry into the signs of the Zodiac. The saint's days correspond with those in Digges, ff. 35ᵛ, 36.

Cirenc	Phe + Iac	Nat. mā
Epiphani	Barnā	Mathē
Hilarī	Iōa-bap.	Michāl
Cō Pāu	Pē. Pā	Lūc
Purifi	Dog. bēg	St. Iūd
Valent	Ma. in ag.	Om. San
Māt	Ia Apō	Om. Am.
Annūn	Pet. vi.	Andro.
Georḡ	Dōg. eñd.	Nicola.
Marc̄	Bartho	Cōce. ma
	de col. 10	Thō apō
		Nate do
		Ste Ph;
		Iohn eva
		Innocen.

[1] The Aspects of the Planets, or Syzygies, have been clearly explained by M. F. Beckius in his *Ephemerides Persarum Comm.*, c. iii, 1695.

14. On page 4.

Thē Table declareth what signe the ☽ is in

Monethē	Da ies	pri me	The 12 Signes	To let blud	To purg.	To bath.

Digges, *Prognostication*, 1555, gives an identical table on f. D. iii; or f. 18 of the 1564 edition.

15. On page 5.

The prim̄	The sōndā letter	The first ten sō	Eastē daē	Roga tion	Whit sonda	Betwixt Whit fōn & mid sō
		Febr	Marc	April	Maie	Wek. dai

This table is continued on p. 6.

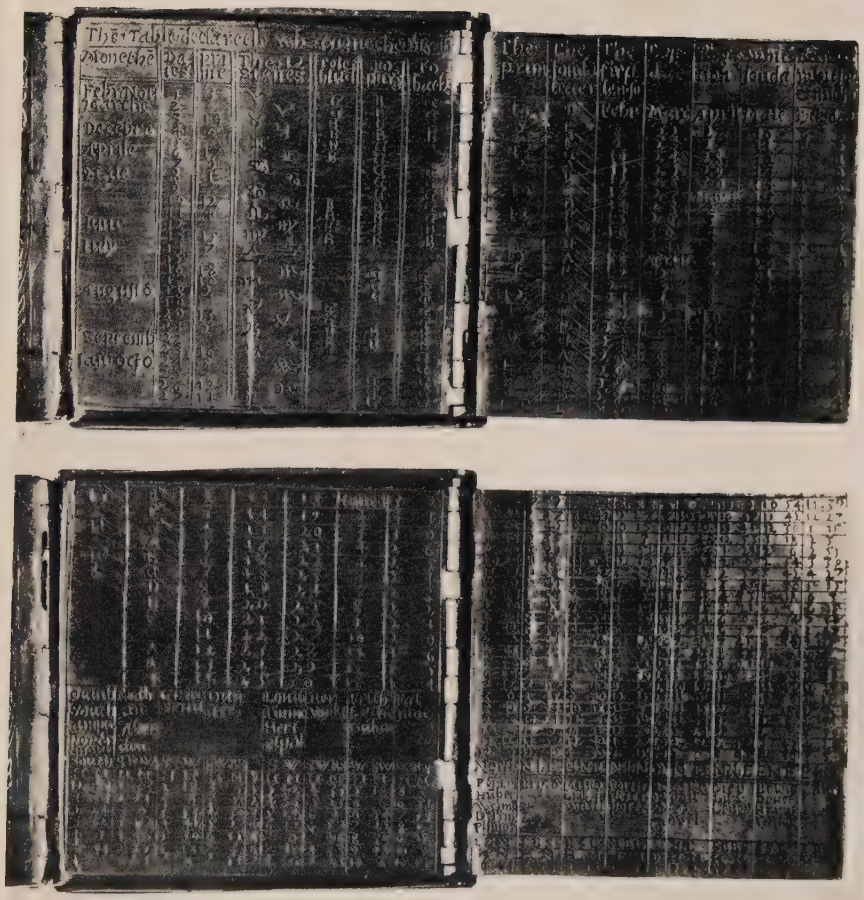
See Digges, *Prognostication*, f. 21v, for a similar table.

16. Tide Tables for British and Channel Ports (on three pages 6, 7, and 8).

Quinb South ampto ports mout	Redb an Aber den	Grave send	Dun dee		Lo dē Tinmō Hert elpōl	Ber wyke	Frith[1] Lythē Dūbar	Fal mot
South	S B W	S S W	S W B S		S W	S W B S	S W	W B S
H M	H M	H M	H M	☽ 1 2 3 ⋮ 30	H M	H M	H M	H M

[1] Erith in Digges, *Prog.*

14 15



15 *continued and* 16 16 *continued*

NO 49. V. C.'S POCKET DIAL, 1554

Bodleian Library

North	N b E	N N E	N E b N	☽	N E	N E b E	E N E	E b N
Foi Lin[1] Hūber Weimō Dertm Plimot	Bristo	Milfo Brwg water	Portl Peter porte	Age of ye	Orkn Pole Or wel	Diep Lux Lenoy	Boloig Douer Harw Yarmo	Calice
East	E b S	E S E	S E B E		S E	S E B S	S S E	S B E
				☽ 1 2 3 30				
West	w b N	W N w	N W b w	☾	N w	N w b N	N w	N b w

Digges printed tide tables, which are practically identical, in his *Prognostication*, 1555 edit., f. F. i, and on f. 30 of the 1564 edit.

Some Early Tidal Tables in a thirteenth-century MS. (Cott. Jul. D. VII, f. 45ᵛ) have been reprinted by Halliwell, *Rara Math.*, p. 55.

Flod at London Brigge.

Aetas Lunae	Horae	Minuta
1	3	48
2	4	36
3	5	24
4	6	12
.	.	..
30	3	0

Inside back cover.

17. A circular Lunar Calendar for the years 1554 to

[1] Litt in Digges, *Prog.*

1579 showing the D[ays] H[ours] and M[inutes] of the 'LVNACO' in 4 circles round a Crescent Moon.

About the English workmanship of this dial there can be no doubt, but the identity of V. C. is still quite uncertain. I would suggest that he was the master, perhaps even the father, of Humphrey Cole, the distinguished maker of the next dial, in which case V. C. might stand for Vmfredus Cole.

An instrument that is similar to V. C.'s Pocket Dial is

Cole's Pocket Book-Dial. **1568.**

Brass gilt. Lewis Evans Collection.

'*Hvm fray Coole made this boke anno 1568.*'

It is therefore the earliest example known of the work of this famous maker.

Cover with engraved decoration representing in a roundel a flowering tree in the branches of which sit birds singing '*Jugge, Jugge, Jugge, Jugge*'. (Jugge was not only the song of the nightingale, but Richard Jugge was the name of a printer of Almanacks 'dwelling at the north dore of Pouls' in 1548.) The border is ornamented with scroll-work, squirrels and snails.

Instruments, &c., within.

1. In Cover, 'Quadrans Geometricum' and 'Quadrans Astronomicum'.
2. Two Boxes of Instruments, the one for '*Compase Square & Rule*', and the other for '*The Wrytinge penne*'.
3. Compass.
4. Dial and Clinometer.
5. Table of latitudes of Towns, including Oxford 51° · 50.
6. Calendar for January to June [rest missing].

154. Telugu Almanack. For **1632.**

MS. Laud Or. e. 1 (R), Bodleian Library.

Pres. by Archbishop Laud.

155. Pocket Clog Almanack. For the year **1636.**

Bodleian Library.

Pres. by Archbishop Laud.

In the form of eight small wooden tablets.

156. Clog Almanack.

Given in 1682 by Richard Davis of Sandford, Oxon.
Bodleian Library.

Described by Plot, *Nat. Hist. of Staffordshire*, 1686, pp. 418-32, and engraved in the *Anglican Church Calendar*, published by Messrs. Parker.

157. Anglo-Saxon Almanack or Staffordshire Clog.
No. 343, Ashmolean Museum.

Presented by Dr. Plot, *c.* 1684, cf. Plot's *Staffordshire*, p. 420, and Fosbroke's *Ency. Antiq.*

158. Runic Calendars or Danish Almanacks.
Nos. 344–7, Ashmolean Museum.

Presented by John Heysig, Esq., 1683.

159. Runic Primstaff. For 1690–1700.
Bodleian Library.

In the form of a walking stick. Given by Mr. Guy Dickins A.D. 1749, a gentleman commoner of Christ Church, who had been for several years ambassador in Sweden, where doubtless he obtained it.

Pointer (*Oxon. Acad.*, p. 143), in describing the instrument, implies that he was the actual donor of it. The explanation is in MS. Rawl. D. 707.

160. New AL - MON - AC for Ever. 1681.
00. 2. 10. Christ Church Library.

By R. W. F.R.S.

161. Perpetual Calendar in the form of a token. 1690.
Diameter $1\frac{1}{4}$ inches. Bodleian Library.
'W. Foster.'

Rev.

* The Figures in the Rounds are the 12 Months 1 t 3 Mar. 2 Ap: &c. Observe what day March enters upō, for the figures below are the days of the Month, & those yᵗ stand under your Month are all the same day of yᵉ week and other week days follow in order yᵗ day of yᵉ Mōth figure of yᵉ mōth & yᵉ Epact aded is the ☽ > >

Obv.

14	25		Epact		1690		–	9
3	(1)	(6)	(3)	(8)	(5)	(7)	(12)	17
	(9)	(0)	(11)	(0)	(2)	(10)	(4)	
22	••	••	••	••	••	••	••	28
	1	2	3	4	5	6	7	
1	8	9	10	11	12	13	14	9
29	15	16	17	18	19	20	21	20
	22	23	24	25	26	27	28	
1	29	30	31	W.	F	o s	t e r.	1
	7							

162. Perpetual Calendar. **17th cent.**

Ashmolean Museum.

Square table for finding the days of the month similar to the above, but with the 4th and 12th months transposed in the first two rows.

Engraved on the handle of *Absalom Leech's* walking stick. See p. 124 and vol. i, p. 160.

163. Perpetual Calendar. **1718.**

Bodleian Library.

'A. BVCKLEY.'

Obv. Square table for finding the day of the month surrounded by a ring of dates of the beginning and end of terms, e. g. 'MTB' (=Mich. Term Begins), &c.

Rev. Five concentric Circular Scales for lunar calculations and for finding Easter. The three outer circles are marked 'EASTER', '☽ SOUTH', 'EPACT', the two inner circles give the names of the months and the figures '8-4, 4-8'.

164. Perpetual Calendar.

Diameter $1\frac{4}{5}$ inches. Bodleian Library.

Obv. 'DAY OF THE MONTH FOR EVER.'

A copper disk, marked with the days of the month, can be moved so that any day is brought opposite the days of the week marked on the outer border of the disk below.

Rev. Two similar rings encircling a scale for showing the 'MOON'S AGE, PHASES AND SOUTHING'.

A Perpetual Regulation of Time. **1753.**

In the possession of Capt. Spencer Churchill of Northwick Park.

A large card with movable card circles for setting so as to show the Age of the Moon; the Increase and Decrease of the Moon; the time of High Water at London Bridge; times of Sunrise, Sunset, Sun's place in the Zodiac, &c.; Easter days, Epact, Dominical Letters and Feasts for the years 1753 to 1852; and a Regal Table. This card, published by permission of the Company of Stationers, is mounted in a frame bearing a bent barometer and a thermometer. See vol. i, p. 245.

165. Calendar in the Form of a Token. For 1753.

Diameter 1½ inches. Bodleian Library.

'Iohn Poweli, Birmingham.'

Obv. Table of dates of Sundays in each month, of Ash Wednesday, of 'Hillary' and Michaelmas Terms.

Rev. Table of dates of New and Full Moon, of Whit Sunday and of Easter and Trinity Terms.

Calendarium Perpetuum.

Gilt brass. L. Evans coll.

'J. O. Hannes Carte Londini fecit.'

Shows the 'Sunnes Entrance' into the Signs of the Zodiack, &c.

THE TELESCOPE

The importance of carefully preserving original pieces of scientific apparatus is well illustrated in the history of the Telescope. Unless a claim to originality of invention is supported by the confirmatory evidence of the instrument itself, or by so full a specification as to make it unequivocal, an early inventor may not receive the credit he deserves. Purely literary allusions to an invention are apt to be either passed over or treated as fabulous.

Thus it has come about that the invention of the telescope has been attributed to many: to GALILEO, who should rather be held to have advertised its utility by his astronomical discoveries; to the DUTCH MAKERS OF SPECTACLES, who appear to have been the first to put it as a commercial article upon the market, thus providing contemporary savants with a handy and complete instrument, the optical tube; to the Elizabethan writer and philosopher, LEONARD DIGGES, of Oxford, who, as will be seen, must have constructed a reflecting telescope, and to the still earlier 'Doctor Mirabilis', ROGER BACON. But let them speak for themselves.

The earliest of all, ROGER BACON, who died about 1294, wrote—

> 'Glasses or diaphanous bodies may be so formed that the most remote objects may appear just at hand, and the contrary, so that we may read the smallest letters at an incredible distance, and may number things, though never so small, and may make the stars also appear as near as we please.' [1]

It is inconceivable that man should have arrived at such a thought without some practical experience, or without information of the practical experience of others. We have no evidence that Bacon had this practical experience: but there is none to show that he had not. He may have been repeating what was common knowledge among the initiates of his time, but

[1] Bacon, *Epist. ad Parisiensem*, 'Of the secrets of Arts and Nature', cap. 5. Also see *Opus majus*, iii, cap. 4, p. 357. Jebb's edit. 1733.

until an earlier authority is forthcoming, the name of Roger Bacon must remain associated with the first notice of the telescope, for certainly his writings have been a source of inspiration to later inventors.

About a century later, the specific name by which telescopes were commonly known is used by Chaucer, *c.* 1386, in a sense that implies that the instruments referred to were well known in his time. The 'queynte mirours and . . . perspectyues' of the *Squire's Tale* may well have been the 'perspective glasses' of a later day.

The tradition of Roger Bacon's telescope was never wholly lost; about the middle of the sixteenth century ROBERT RECORDE reported—

'Great talke there is of a glasse that he made in Oxforde in whiche men myght see thynges that wer doon in other places, and that was iudged to bee done by power of evill spirites. But I knowe the reason of it to bee good and naturall, and to be wrought by Geometrie (sythe perspective is a parte of it).'[1]

There is no reason why any one, into whose hands an optical MS. of Bacon's might have fallen, should not have constructed a telescope for himself. And such indeed was the case about 1550, or earlier, when LEONARD DIGGES, who had been an undergraduate at University College, had profited so greatly by studying a Baconian MS., now presumably lost, that he 'was able by *Perspective Glasses* duely scituate upon convenient *Angles* in such sorte to discover every particularitie in the countrey rounde about wheresoever the Sunne beames mighte pearse'.[2]

Digges by another instrument would even seem to have anticipated the Newtonian Reflecting Telescope by a hundred years.

'By concave and convex mirrors of circular (spherical) and parabolic forms, or by paires of them placed at due angles, and using the aid of transparent glasses which may break, or unite, the images produced by the reflection of the mirrors, there may be represented a whole region; also any part of it may be augmented, so that a small object may be discerned

[1] R. Recorde, Preface to the *Pathway to Knowledge, Booke of the principles of Geometrie*, 1551.

[2] Th. Digges, son of Leonard Digges, *Stratioticos*, p. 189, 1579.

as plainly as if it were close to the observer, though it may be as far distant as the eye can descrie.'[1]

Leonard Digges died about 1570. Had he lived longer, he would no doubt have given his discoveries in Optics to the world and have been numbered among the greatest of the inventors that Oxford has produced.

His son, Thomas, reasserted his father's claim as a discoverer:

'my father by his continual paynfull practises, assisted with demonstrations *Mathematicall*, was able, and sundrie times hath by proportionall Glasses duely situate in convenient angles, not onely discovered things farre off, read letters, numbred peeces of money with the very coyne and superscription thereof, cast by some of his friends of purpose uppon Downes in open fieldes, but also seven myles of declared what hath been doon at that instante in private places.'[2]

my father by his continual paynfull practises, assisted with demonstrations *Mathematicall*, was able, and sundrie times hath by proportionall Glasses duely situate in conuenient angles, not onely discouered things farre off, read letters, numbred peeces of money with the very coyne and superscription thereof, cast by some of his frœnds of purpose vppon Downes in open fieldes, but also seuen myles of declared what hath bœn don at that instante in priuate places:

FACSIMILE OF PASSAGE DESCRIBING THE PERFORMANCE OF LEONARD DIGGES'S TELESCOPE.
Pantometria, 1571.

'Marveilous are the conclusions that may be performed by glasses concave and convex, of Circulare and parabolicall formes, using for multiplication of beames sometime the aide of Glasses transparent, which by fraction should unite or dissipate the images or figures presented by the reflection of others'. . . . 'But of these conclusions I minde not here more to intreate, having at large in a volume by itselfe opened the miraculous effects of perspective glasses.'[3]

But, as in the case of Roger Bacon, the actual instruments which would have convinced the world regarding the real inventor of the telescope are not now extant.

[1] *Pantometria*, 1571. The exact wording varies in different editions.

[2] Preface to *A Geometrical Practice named Pantometria*, 1571.

[3] *Pantometria*, i, chap. 21, published by Thomas Digges in 1571.

And Dr. Dee, writing about the same time, also speaks of 'perspective glasses' as if they were familiar optical instruments of great use to the commander of an army who might desire to ascertain the strength of his enemy.

'He may wonderfully helpe him self, by perspective Glasses. In which, (I trust) our posterity will prove more skillfull and expert, and to greater purposes then in these dayes, can (almost) be credited to be possible.'[1]

Still more convincing appear to us the descriptions in W. Bourne's *Treatise on the Properties and Qualities of Glasses for Optical Purposes* written about 1580-90.

Chap. V.

'In what order to make a glass, that you may looke thorow, that shall forther your sighte, and to have a small thynge to seem bigg, which ys very necessary for perspective: And yt may bee so made, that you may discerne a small thinge, a great distance, and specyally by the ayde of other glasses. [Here we have the principle of the Refracting Telescope.]

. . . the smallest sorte of them, commonly called spectacle glasses . . . ys grounde vppon a toole of Iron, made of purpose, somewhat hollowe, or concave inwardes. . . . The Glasse, after that yt ys full rounde, ys made fast with syman vppon a smalle block, and so grounde by hande, vntill that yt ys bothe smoothe and also thynne, by the edges, or sydes, but thickest in the middle.

. . . this glasse . . . wille have three marvellous operacyons or qualityes as hereafter you shall see.'

Chap. VI.

'In the beholding any thinge thorowe the glasse, you standinge neare unto the Glasse, yt will seeme . . . to bee but little bigger, then the proportion ys of yt: But as you do stande further and further from yt, so shall the perspective beame, that cometh through ye glasse, make the thinge to seeme bigger and bigger, vntill suche tyme, that the thinge shall seeme of a marvellous bignes.'

Chap. VII.

'The quality ys, if that the sunne beame do pearce throughe yt, at a certain quantity of distance, and that yt will burne any thinge, that ys apte for to take fyer. . . .'

[1] *The Elements of . . . Euclide*, 1575. Preface, p. b. 1

Chap. VIII.

. . . 'the toppes ys turned downwardes.'

Chap. IX. [*Reflecting Telescope.*]

The effects that may bee done with these two last sortes of glasses: The one concave with a foyle, vppon the hylly syde, and the other grounde and polisshed smoothe, the thickest in the myddle, and thinnest towordes the edges or sydes.

'For that the habillity of my purse ys not able for to reache, or beare the charges, for to seeke thorowly what may bee done with these two sortes of glasses, that ys to say, the hollowe or concave glasse: and allso that glasse, that ys grounde and polysshed rounde, and thickest on the myddle, and thynnest towardes the sydes or edges, Therefore I can say the lesse vnto the matter. For that there is dyvers in this Lande, that can say and dothe knowe muche more, in these causes, then I: and specially Mr. Dee, and allso Mr. Thomas Digges, for that by theyre Learninge, they have reade and seene many moo auctors in those causes: And allso theyre ability ys suche, that they may the better mayntayne the charges: And also they have more leysure and better tyme to practyse those matters, which ys not possible for mee, for to knowe in a nombre of causes, that thinge that they doo knowe. But not withstanding upon the smalle proofe and experyence those that bee but vnto small purpose, of the skylles and knowledge of these causes, yet I am assured that the glasse that ys grounde, beynge of very cleare stuffe, and of a good largenes, and placed so, that the beame dothe come thorowe, and so reseaved into a very large concave lookinge glasse, That yt will shewe the thinge of a marvellous largenes, in manner vncredable to bee beleeved of the common people. Wherefore yt ys to be supposed, and allso, I am of that opinyon, that havinge dyvers, and sondry sortes of these concave lookinge glasses, made of a great largenes, That suche the beame, or forme and facyon of any thinge beeynge of greate distance from the place, and so reseaved fyrste into one glasse: and so the beame reseaved into another of these concave glasses: and so reseaved from one glasse into another, beeynge so placed at suche a distance, that every glasse dothe make his largest beame.

'And so yt ys possible, that yt may be helpped and furdered the one glasse with the other, as the concave lookinge glasse with the other grounde and polysshed glasse. That yt ys lykely yt ys true to see a smalle thinge of very greate dis-

La dioptrique oculaire
Par le Pere Cherubin d'Orleans
Capucin
le Pautre del.

tance. For that the one glasse dothe rayse and enlarge, the beame of the other so wonderfully.

'So that those things that Mr. Thomas Digges hathe written that his father (Leonard) hathe done, may bee accomplisshed very well, withowte any dowbyte of the matter: But that the greatest impediment ys, that yow can not beholde, and see, but the smaller quantity at a tyme.'

There can, I think, be no reasonable doubt that Leonard Digges of University College was the real inventor of Telescopes both Refracting and Reflecting, and that he thus forestalled Galileo by many years.

That Digges's glasses were familiar to others in Oxford receives some confirmation from the *Report* of THOMAS HARIOT, the mathematician, born in Oxford, it is believed in the parish of St. Mary, in 1560. 'A perspective glass whereby was showed many strange sights' was among the mathematical instruments which he used to excite the wonder of the natives of Virginia in 1585-6.

This remarkable man, the mathematical tutor of Sir Walter Raleigh and correspondent of Kepler, was a B.A. of St. Mary's Hall in 1580. He accompanied Sir Richard Grenville's expedition to Virginia in 1585 as a surveyor, and on his return published 'A Brief and True Report of the new-found Land of Virginia' in 1588.

During the latter part of his life he had a pension of £300 a year and a residence at Sion House assigned to him by his patron Henry, Earl of Northumberland, to whom he had been introduced by Raleigh, when both were prisoners in the Tower. Hariot, Robert Hues, and Warner were known as the 'three Magi' of the Earl of Northumberland; 'they had a table at the Earle's chardge, and the Earl himself had them to converse with, singly or together'.[1]

In spite of poor health, Hariot was a 'universal philosopher', and made many discoveries of first-rate importance especially in mathematics, but his failure to publish them led to his being anticipated by others. However, his treatment of equations and improvements in notation practically gave to algebra its modern form. He invented the signs of inequality > and <.

[1] Aubrey, *Lives*.

He applied the telescope to celestial objects almost as early as Galileo. In July 1609 he is said to have made with its help two sketches of the moon, and he began on 17 October, 1610, a series of observations on 'the new-found planets about Jupiter', continued until 26 February, 1612. Between 8 December, 1610, and 18 January, 1613, he made 199 observations of sun-spots, and determined from them the sun's axial rotation. His later astronomical observations were made with telescopes that magnified up to fifty times.

Apparently he instructed his pupil, Sir W. Lower, in the use of the telescope about 1610 when Lower wrote a letter to him beginning

> I have received the perspective Cylinder that you promised me and am sorrie that my man gave you not more warning, that I might have had also the 2 or 3 more that you mentioned to chuse for me. . . . According as you wished I have observed the Mone in all his changes. . . . In the full she appears like a tarte that my Cooke made me last Weeke, here a vaine of bright stuffe, and there of darke, and so confusedlie al over. I must confess I can see none of these without my cylinder.[1]

These perspective cylinders may have been of Dutch origin, although it has also been suggested that they were made by Hariot's instrument maker, one Christopher Tooke.

For the further history of the instrument we must now pass over to Holland, where in Middelburg the lens makers Hans Lippershey and Zacharias Jansen, and at Alkmaar James Metius (= Jacob Adrianzoon) all contrived to make refracting telescopes with concave eyepieces so nearly about the same time, that it has cost much research and controversy to determine that it is the first-named who should receive the palm of priority.[2] Even their countryman Huygens did not venture to decide with certainty on one name.

Lippershey received 900 florins for one of his telescopes on 6 October, 1608, and further orders soon poured in. These Dutch telescopes were no doubt made in a very saleable form, and the keen business instinct of

[1] Lower's letter is quoted from F. V. Morley's interesting paper on *Thomas Hariot*, in the *Scientific Monthly*, Jan. 1922.

[2] G. Moll of Utrecht, *Journ. Roy. Inst.*, 1831, i, p. 319.

the spectacle makers had more to do with the immediate recognition of the value of the instrument than is commonly realized.

The French ambassador at the Hague was in treaty for a telescope that he wished to send to his king, Henry IV; one was even offered for sale at Frankfort in the autumn of 1608 to a friend of Simon Marius; who is stated to have constructed one himself from the description; in May 1609 a Frenchman offered a telescope for sale to Count di Fuentes in Milan[1]; and about the same time Galileo, happening to be in Venice, received information which enabled him to construct a similar perspective instrument the very day after his return to Padua (from Venice), by fitting a convex and a concave lens into the ends of a leaden tube. In short, by one way or another the Dutch telescopes found their way all over Europe almost more rapidly than any other invention and were immediately imitated. In February 1610[2] they were already being made in London.

The clear sky of Italy and the assiduity of a Galileo soon proved the power of the instrument to annihilate distance. Almost immediately it brought within human ken the Satellites of Jupiter, Lunar hills and plains, the Sun's spots, the crescent form of Venus, the ring of Saturn, the star clusters and the nebula of Andromeda. These were the firstfruits of the exploration of the universe, thus rendering 1610 in the history of Astronomy an epoch more important than to geography are the discoveries of 1492.

Thus has the name of Galilean come to the telescope of Lippershey.

Early news of Galileo's discoveries was sent to James I by an Oxford man, Henry Wotton, of Queen's and New College, then resident in Italy, who, moreover, in a letter dated March 13, 1610, distinctly dissociates the original invention of the telescope from Galileo.

'I send herewith unto his Majesty the strangest piece of news (as I may justly call it) that he hath ever yet received from any part of the world; which is the annexed book[3] (come abroad this very day) of the Mathematical Professor at

[1] Sirturus, *de Telescopio*, 1618.

[2] Rigaud, *Account of Harriot's Astronomical Papers*, 1833, pp. 23, 26, 46.

[3] Galileo, *Sidereus Nuncius*.

Padua, who by the help of an optical instrument (which both enlargeth and approximateth the object) invented first in Flanders, and bettered by himself, hath discovered four new planets rolling about the sphere of Jupiter, besides many other unknown fixed stars; likewise, the true cause of the *Via Lactea*, so long searched; and lastly, that the moon is not spherical, but endued with many prominences, and, which is of all the strangest, illuminated with the solar light by reflection from the body of the earth, as he seemeth to say. So as upon the whole subject he hath first overthrown all former astronomy, and next all astronomy. . . . By the next ship your Lordship [the Earl of Salisbury] shall receive from me one of the above-named instruments, as it is bettered by this man.'[1]

All the early opticians must have experimented with two convex lenses in combination, but probably rejected that type of instrument on finding that the image was upside down, and preferred to keep to the telescope with the concave eye-lens. As early as 1611 Kepler had pointed out the advantages of the former arrangement of lenses, and observers slowly learnt that the inversion of spherical bodies in boundless space was not of much consequence after all.

The first **Keplerian telescope** which was sufficiently powerful for further discoveries of an epoch-making nature was a 12 foot made in 1655 by CONSTANTINE HUYGENS,[2] private secretary to King William III, in collaboration with his brother the great astronomer. By its means the *Systema Saturnium* (1659) was truly explained for the first time, and it led the way to the construction of object glasses of greater and greater focal length, such as the three great lenses by Constantine Huygens now in the possession of the Royal Society.

In Italy, too, long-focus lenses made by the Roman optician Campani and the Venetian Borelli had their successes.

Campani's 35-foot telescope showed Saturn's fifth satellite (Rhea) in 1672. His instruments of 100 feet and 136 feet yielded the third and fourth satellites in 1684, and

[1] Pearsall-Smith, *Letters of Wotton.*

[2] Uytenbrock, *Oratio de fratribus Christiano atque Constantino Hugenio, artis dioptricae cultoribus*, 1838.

these successes, appearing to be in proportion to the length of the instrument, led many to the most extravagant expectations. Object glasses are known to have been ground of a focal length of 266 feet by Hartsoeker, 320 feet Auzout,[1] and HOOKE of Christ Church is said to have proposed one of 10,000 feet, or nearly two miles, 'in order to see animals in the moon'. Still it was with his 36-foot telescope pointed at γ Draconis through an aperture in the roof of Gresham College from July to October 1669 that Hooke achieved one of his greatest successes, the determination of the supposed parallax of a fixed star. His result was naturally not accurate, but it led to Bradley's discovery of aberration. Hooke was the first to observe a star by daylight *c.* 1670.

In the eighteenth century the tubes of **Perspective glasses** were of several sorts and made of various materials. Some are made of stiff paper glued together, covered with parchment or shagreen or leather; some consist of single tubes, made of light dry wood; others of several lesser tubes, sliding one within another. The glasses are fixed in the tubes in wooden cells, so as to be easily taken out and put in again, by means of screws, in order that dust or moisture may be readily wiped off from them. At the end of every one of the inward tubes is fitted a wooden ring (= diaphragm) to hinder the lateral spurious rays from coming to the eye, which is found by experience to be more use than could be thought; these rings are generally furnished with female screws in those places whereat the glasses are seated. The Perspectives of 3 or 4 feet, which have but one wooden tube, are most handy, especially, if at each end, instead of covers that screw and unscrew, they have thin sliding pieces of brass for such.[2]

In England Kepler telescopes were made for or by Sir Paul Neile and Messrs. Reeves and Cox. During the latter end of the seventeenth century Wm. Ball of Mamhead, Devonshire, using an instrument of 38 feet focus observed the double nature of Saturn's ring.

But telescopes of extreme focal length did not find favour in England. Our Savilian Professor Caswell informed Uffenbach in Oct. 1710 that 'when Halley

[1] Arago, *Annuaire pour 1844*, p. 381.
[2] Stone's 1758 supplement to Bion, *Math. Instr.*, p. 283.

was with the famous Hevelius, he discovered that they could not see or observe anything with his telescope of 300 feet, and that his other telescopes were useless, because on account of their length, the centres of the lenses cannot be brought into a straight line. He asserted also that lenses of over great size were of no use, and that neither Newton or Marshall here in England could produce anything of value in this kind.'[1]

In 1690 JOHN MARSHALL was practising as a manufacturing optician in the Strand with such success that on January 18, 1693–4, his methods and results received the official approval of the Royal Society. The original letter that he received, signed by Edm. Halley, has

THE

ROYAL SOCIETY'S

LETTER.

I Have (by Order of the Royal Society) ſeen and examined the Method uſed by Mr JOHN MARSHALL, for grinding Glaſſes; and find that he performs the ſaid Work with greater Eaſe and Certainty than hitherto has been practiſed; by means of an Invention which I take to be his own, and New and whereby he is enabled to make a great number of Optick-Glaſſes at one time, and all exactly alike; which having reported to the Royal Society, they were pleaſed to approve thereof, as an Invention of great uſe; and highly to deſerve Encouragement.

Lond. Jan. 18. 1693. 4.

By the Command of the Royal Society;

EDM: HALLEY.

Note, There are ſeveral Perſons who pretend to have the Approbation of the ROYAL SOCIETY; but none has, or ever had it, but my ſelf; as my Letter can teſtifie.

been facsimiled in the illustrated edition of Green's *History of England*, p. 1575.

[1] Uffenbach, October 6, 1710.

One certainly, and perhaps two, of the oldest known specimens of his art are in the Orrery Collection at Christ Church. Their many draw-tubes covered with vellum are surprisingly light and smooth in use.

For an early illustration of a telescope with a paper or cardboard tube cf. Zahn, *Oculus artificialis*, 1685, p. 188. The Orrery instruments by Marshall and Wilson appear to be constructed in accordance with the principles set out at length by Zahn.

NON-ACHROMATIC TELESCOPES

Perspective Glass

166. ½-inch Ivory mounted 1-draw Galilean or Perspective Glass. **c. 1710.**

Orrery Coll. 29.

Outer body ornamented with gold tooling, 4 inches long when closed, 4½ inches when extended. Draw-tube covered with green vellum. Object glass, 4½ inches focus, and eyepiece are mounted in ivory cells with screw caps.

We place this example of the 'least kind of Perspective Glasses' first, because it represents the telescope with the concave eye-lens, the invention of Galileo in 1609, so famous for the great discoveries he immediately made with it and now so familiar in the form of the common opera-glass. Galileo's best telescope is said to have been 3 feet long. Within a century of its invention Galilean telescopes were being made in considerable numbers in Paris.

Keplerian Telescopes

Four years later, and apparently for the first time, Gascoigne used the Kepler telescope for observation. He introduced a micrometer into the focus of the eyepiece and made measures which were published by Flamsteed. A similar instrument was used for observation by Scheiner (*Rosa Ursina*, 1630), but several years elapsed before any discovery of first-class importance was made with the Keplerian Telescope. However, in

1655 Huygens discovered a satellite of Saturn with an objective of 12 foot focal length.

The first Fellows of the Royal Society considered the matter of lens-grinding to be of such importance, that on April 10, 1661, they appointed a committee of Lord Brouncker, Sir Robert Moray, Sir Paul Neile, Dr. Wallis, Dr. Goddard, and Mr. Wren to consider all sorts of tools and instruments for making glasses proper for perspectives for the use of the Society.

Keplerian Telescopes of long focus

In the summer of 1686 Constantine Huygens completed the three large object glasses of great focal length which are now in the possession of the Royal Society. They have been mounted in brass cells under the direction of Warren de la Rue. All three glasses are full of air bubbles.

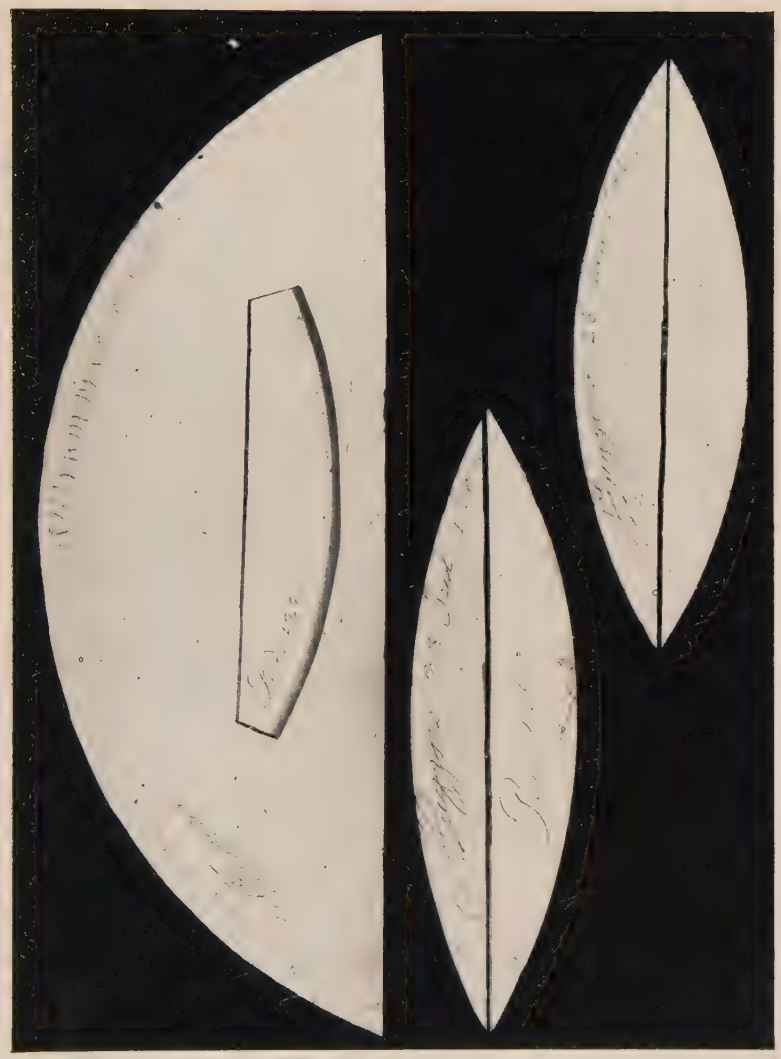
Object glasses.

1. **7½-inch aperture, 122 foot focus.**
   Inscribed—*4, June 1686 C. Huygens.*
   Vitrum praestantissimum
   Wm. Derham, Royal Soc. No. 22 Ped. 122
2. **8-inch aperture, 170 foot focus.**
   Inscribed—*26, June 1686 C. Huygens.*
   Presented by Sir Isaac Newton, Royal Soc. No. 23
3. **8¾-inch aperture, 210 foot focus.**
   Inscribed—*23, July 1686 C. Huygens.*
   Pres. 1767[1] *by Rev. Gilbert Burnet F.R.S., Royal Soc. No. 24*

The first lens was the objective of Huygens' *Aerial Telescope* which, with an eyeglass of 6 inches focal length and apparatus for adjustment, was presented by Huygens to the Royal Society in 1691. The apparatus for using the eyepiece was the work of Hooke. Additional apparatus by Dr. Pound was presented by Dr. Bradley, by whom the telescope was used at Wanstead.

Huygens had already described his method for using

[1] The date of presentation has also been stated as 1724, but this may refer to the date of the presentation of No. 2 by Newton. Weld, *Hist. Royal Soc.*, p. 330.



HUYGENS' SIGNATURES ON THREE OBJECT GLASSES, 1686

The Royal Society

a telescope without a tube in *Astroscopia Compendiaria Tubi Optici Molimine Liberata*, Hague, 1684, and Hooke was entrusted with this glass with the view of constructing an apparatus for its use. In the meantime Halley was ordered to 'view the scaffolding of St. Paul's Church, to see if that might not conveniently serve for the present, to erect the object-glass thereon, for viewing such of the celestial objects as now present themselves'.[1]

The object glass, mounted in a short tin tube, was rigidly fixed to the side of a long stick like a sky rocket to its stick. The whole was attached to a convenient tree or pole by a ball-and-socket joint, allowing free movement, at the height necessary for making the desired observation.

A silk cord was attached to the tail end of the stick, so that the observer, by gently pulling the cord, could give any desired alinement to the object glass.

The eyepiece was also fixed upon a short stick which could be slid up or down the line, until distinct vision was obtained.

The same object glass, lent by the Society in 1717, was mounted by James Pound in Wanstead Park on the maypole just removed from the Strand, and procured for the purpose by Sir Isaac Newton, who appears also to have assisted Pound financially. A copy of verses affixed to it by a local wit began:

> Once I adorned the Strand,
> But now have found
> My way to pound
> In Baron Newton's land.

The inconveniences of the 'aerial' instrument were severely commented upon by J. Crosthwait.[2] But it had its successes in Pound's hands. The observations he made with it of the five known satellites of Saturn enabled Halley to 'rectify' their movements,[3] and the micrometrical measures of the disks of certain of the planets made by its use were turned to good account by Newton (*D. N. B.*).

[1] Royal Society *Journal-book*, vol. ix, p. 87, quoted in Weld's *History of the Roy. Soc.*, p. 330.

[2] Baily, *Flamsteed*, p. 335.

[3] *Phil. Trans.* xxx. 772.

Even the inventive genius of Captain Smyth[1] was 'puzzled to know how they contrived to get the eye and object-glasses of these unwieldly machines *married*, or brought parallel to each other for perfect vision, and so desirous of comparing the performance of one of them, that I was about to ask the Royal Society's permission to erect the aerial 123-foot telescope in their possession. The trouble, however, promised to be so much greater than the object appeared to justify, that I laid the project aside,—not wishing to furnish a parallel to the case of the worthy captain, whose veracity having been doubted as to the length of a West Indian cabbage-tree, took the trouble to bring one from Barbadoes to prove his assertion'.

It will be seen that Huygens had adopted a very simple and ingenious method of bringing the optical axes of object glass and eyepiece into line and of keeping them there, even though separated by a distance of 120 feet. In order to keep the eyepiece steady, the observer, whether standing or sitting, was recommended to support his arms on a wooden rest with two feet, holding the eyeglass in one of his hands, which is a readier and more commodious way than to fix the eyeglass upon a three-footed rest.

But those who used these long focus lenses had many difficulties to contend against. One was, to find the object glass!

'When the nights are dark, and a star is to be found in the telescope, a lanthorn is used, which collects the light into a stream, either by transmition through a convex lens, or by reflection by a concave speculum (i.e. a bullseye lantern); for by directing this stream of light till it falls upon the object glass, and makes it visible, it is easy for the observer to change his place, 'till he finds the star is covered by the middle of the object glass, and then to apply his eye-glass, which is sooner done than by a telescope with a long tube. By moonlight the object-glass is visible without a lanthorn. But in viewing the moon through the telescope, a paste-board Umbrella should be put about the object-glass, of such a diameter as to cover a space in the Sky above twice as broad as the moon, to intercept that light from coming to the eye, which would pass by the sides of the object-glass, and by mixing

[1] *Cycle of Celestial Objects*, i, p. 370.

CHÉRUBIN'S METHOD OF SUPPORTING A LONG TELESCOPE, 1671.

with the light that comes through the telescope, and would dilate the appearance of the lights and shades in the face of the Moon.'[1]

WREN built the **Monument,** 202 feet in height, in London, to serve as the tube for a long telescope.

Object Glass (Venetian) of 90 foot focal length.

Presented to the Royal Society by J. Hodgson, 1737.

Once in the possession of Flamsteed.

I consider it almost certain that this was the lens of the telescope of 80 feet which Prof. Caswell, our Savilian Professor, saw at Flamsteed's and praised to Uffenbach in 1710. The latter records that Caswell told him that the lens had been obtained from Borelli.

15-foot Telescope with three lenses.
6-foot Telescope with four lenses. } 1697.
2-foot Telescope.

Part of the equipment of the Savilian Museum. See p. 79.

THE ORRERY TELESCOPES

167. 9-foot Refractor. c. 1700.

Vellum tube, closing to $25\frac{1}{2}$ inches. Orrery Coll. (? 28).

Stamped in gold

IOHN MARSHALL, LVDGATE STREET, LONDON.

The outer body (diam. $3\frac{1}{4}$ inches) is covered with vellum, blotched green and red and ornamented with book-binding designs stamped in gold. The draw-tubes, of which there are 9, are of cardboard covered with white vellum, and are marked with pencilled rings to indicate full extension. When fully extended it measures 9 feet. The objective is $1\frac{1}{2}$ inches in diam. with an effective aperture of $\frac{7}{8}$ inch and a focal length of 8 feet. The biconvex eye-lens is mounted far within the eye-cap. All the lenses are mounted in turned lignum vitae mounts. The lenses are provided with wooden screw

[1] Other devices for overcoming the inconvenience of lenses of long focal length were described by Nicolaus Hartsoeker, *Misc. Berol.*, 1710, i, p. 261, and by P. de la Hire, *Mém. de l'Acad.*, 1715.

NO 169 NO. 167

NO. 166

LORD ORRERY'S TELESCOPES, C. 1700

Christ Church

caps to protect the glasses from dust and injury when not in use.

The focal lengths of the lenses and the distances between them are as follows:

	Focal length.	Distance between lenses.
1. Eye-lens	$2\frac{3}{4}$ inches	
2.	$3\frac{1}{2}$ "	$8\frac{1}{2}$ inches.
3.	$4\frac{1}{2}$ "	$8\frac{1}{2}$ "
4. Objective	5 feet	6 feet 6 inches.
	Total length.	7 feet 11 inches.

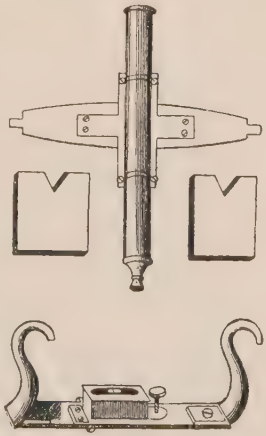
168. 12-foot Refractor. **c. 1700.**

Vellum tube, closing to 30 inches. Orrery coll. 14.

The outer body is covered with white vellum ornamented with bookbinders' stamps tooled in gold. The 9 draw-tubes extend to 12 feet, but the instrument has no object glass. Judging from the diameter of the draw-tubes, $4\frac{1}{2}$ inches at the eyepiece end and 3 inches at the object-glass end, the objective would not have been more than 2 inches in diameter.

The fine and imposing-looking eyepiece is complete. It consists of a field lens of $2\frac{3}{4}$ inches diam. and $11\frac{1}{4}$ inches focal length, and an eye-lens of $1\frac{3}{8}$ inches diam., $2\frac{3}{4}$ inches focal length, mounted about $7\frac{1}{2}$ inches apart in lignum vitae mounts in a vellum eyepiece with a draw-tube.

These Orrery telescopes are of great historic interest as representing the instruments of the time of Flamsteed. When he went to Greenwich in 1676, he had two telescopes, one of 15 and the other of 7 feet focus, a Townley micrometer, and a small quadrant. None of these instruments is now in existence. Halley found no instrument at Greenwich in 1719. His first acquisition was a 5-foot Hook telescope in 1722.



HALLEY'S MERIDIAN TELESCOPE, 1722.
Smith, Opticks.

The telescopes that come near to our Oxford instruments in point of time and style are:

1. The $1\frac{1}{4}$ inch aperture, $11\frac{1}{2}$ in. focal length, 3-draw vellum tube belonging to the Royal Astronomical Society. The cover is tooled in gold like the Orrery instrument but it is fitted with removable erecting lenses so as to serve for terrestrial or astronomical purposes. It is described as circ. 1725.

2. The small 3-draw Terrestrial Hand Telescope in the South Kensington Collection marked JO: HOWE, LONDINI FECIT. The outer body is elaborately decorated with floral designs tooled in gold. The objective and ocular are mounted in ivory. Attributed date, circ. 1700.

3. The small 3-draw tube, without lenses, of the Royal Society. The fleur-de-lys and other tooling on the outer cover indicates French work.

In JOHN MARSHALL's advertisement in the *Whitehall Evening Post* for July 8, 1721, he styles himself:

> Maker of Optick Glasses to His Majesty
> At the Archimedes in Ludgate Street.
> Optick Glasses made to the exactest Perfection by him, who is the only Person approved of by the Royal Society for the Art of Glass-Grinding
>
> John Marshall.

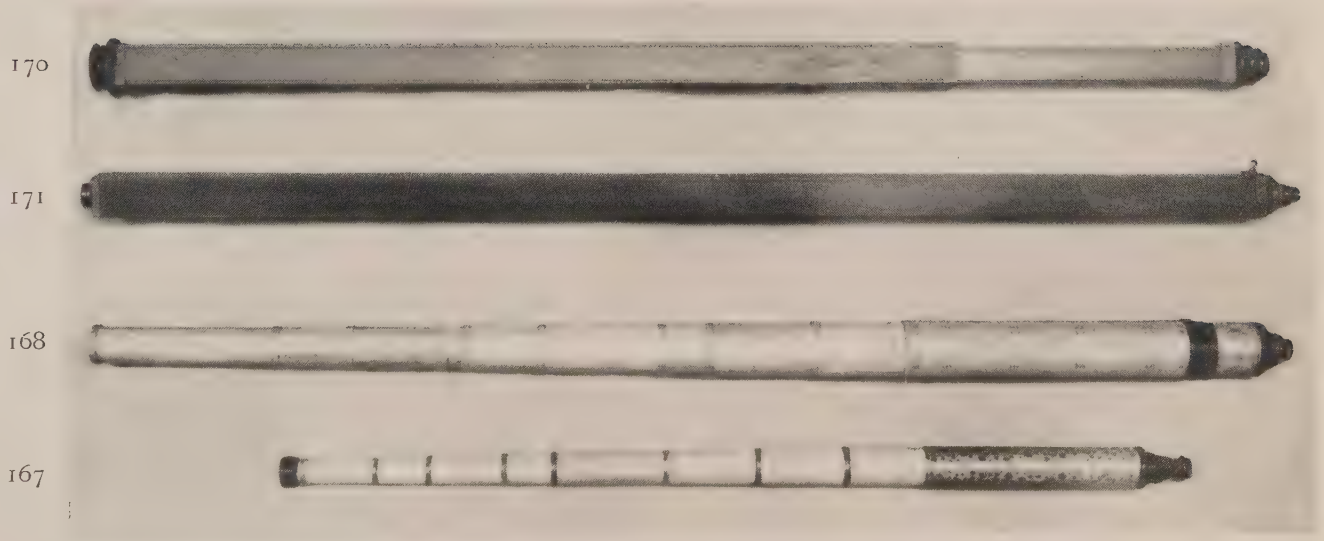
169. 10-inch Silver Terrestrial Telescope. c. 1700.

Orrery coll. 27.

One draw: length open, $10\frac{1}{8}$ inches, closing to $7\frac{1}{2}$ inches.

Both eyepiece and object glass are fitted with sliding caps. The objective is of $5\frac{1}{2}$ inches focus; the four lenses of the erecting eyepiece were mounted in sections of the beautifully made draw-tube which fit together with bayonet joints, engraved for identification with leaves, a ball, and a rose. A small hole is provided to allow the escape of air when the draw-tube is being pushed in. The magnification would have been about 4 diameters.

The invention of the erecting or terrestrial telescope by the application of four lenses is thought to have been made by Campani of Rome.



LORD ORRERY'S TELESCOPES, C. 1700

Christ Church

In this instrument the focal lengths of the lenses and the distances between them are as follows:

	Focal length.	Distance between lenses.
1. Eye-lens	$\frac{1}{2}$ inch	
2.	1 ,,	$1\frac{1}{4}$ inches.
3.	$1\frac{1}{2}$,,	$\frac{3}{4}$,,
4. Missing		$1\frac{5}{8}$,,
5. Objective	$5\frac{1}{2}$ inches	

170. 9-foot Refractor. **1702–10.**

Orrery coll. 17.

Aperture about $1\frac{5}{8}$ inches.

Object glass inscribed *Jac: Wilson, Londini fecit*, mounted in a wood cell. Painted wooden tube 3 inches square, with sliding copper cradle with trunnions for use on the tripod belonging to the $1\frac{1}{4}$-inch refractor described below. Length when closed 6 feet: extension, partly by a square wooden draw-tube, partly by a round green vellum tube, which serves as a fine adjustment.

The eyepiece is unfortunately imperfect, the two lenses, each of $3\frac{1}{4}$ in. focus, nearest the objective being the only parts remaining of an erecting eyepiece. They are mounted in screw mounts, 7 inches apart and about 9 inches from the eye-lens (now missing). Writings on the square draw-tube at 8 feet 6 inches, 7 feet 6 inches, and 6 feet from the object glass describe marks at those points respectively as 'Mark for the longest objective with 3 eyeglasses obiect erected', 'Mark for the shortest objective with 3 eyeglasses obiect erected', and 'Mark for the objective with one eyeglass obiect inverted'. The eye-lens and cap are therefore missing. The metal band round the tube at the eyepiece end once carried a hook for suspension.

This type of instrument was figured in the *Phil. Trans.* for 1667.

Wilson's microscope lenses were famous, but there cannot be many telescope object-glasses signed by him now in existence. So far as we know, this one is unique. It is certainly unusual for so long an instrument to be fitted with an erecting eyepiece.

171. $1\frac{1}{4}$-inch Refractor. c. 1700.
Orrery coll. 16.

Focal length about 7 feet 9 inches.

Lenses, now missing, were formerly mounted in brass mounts with sliding shutters at the ends of the 3-inch square mahogany tube. A sliding cradle with trunnions was used to carry the tube on a tripod stand, but additional steadiness and support was gained by a cord attached to a brass C-hook near the eyepiece end, a

Lord Orrery's $1\frac{1}{4}$-inch Refractor, *c.* 1700.

support necessitated by the great weight of the heavy micrometer that was used with this instrument.

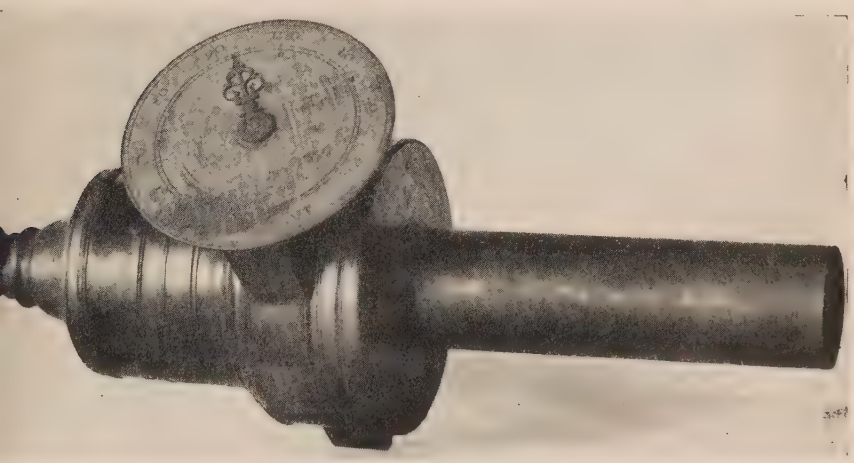
A wooden bracket bearing two wooden 3-inch pulley wheels was found among Lord Orrery's apparatus, which may have been employed for supporting his telescopes.

No doubt the ends of these long though light telescopes were supported by being rested on the top of window sashes, lowered for the occasion, a method that may be referred to in a passage printed in 1748.

> The telescope was again unscrewed, . . . when . . . they were obliged to draw in the optic, and make fast the window against which it had been placed. Eliza Heywood, *Female Spectator*, No. 17 (1748).

172. Micrometer Eyepiece for No. 171. c. 1700.
Orrery coll. 6.

Probably one of the oldest micrometers in existence. Eye-lens of $3\frac{1}{4}$-inch focal length, and $2\frac{3}{8}$ inches in diameter.



No. 172. Micrometer Eyepiece, *c.* 1700.
Christ Church.

Gascoigne used a thread micrometer as early as 1640, but his method was so little known that even in 1717 Derham considered the facts of Gascoigne's invention worthy of a letter to Crabtree, which was printed in the *Philosophical Transactions.* This must have been about the date of the Orrery instrument. Gascoigne's micrometer passed into Townley's hands, and he improved it by adding a double threaded screw.

At the meeting of the Royal Society for July 11, 1667, Mr. Hooke reported that D. Croune 'had received from Richard Townley esq., Mr. Gascoigne's instrument for measuring the diameter of the stars with great exactness; which instrument was afterwards shewed to the Society'.

In 1666 Auzout and Picard also devised a thread micrometer, and in 1676 Römer used thirteen silk threads for the same purpose.

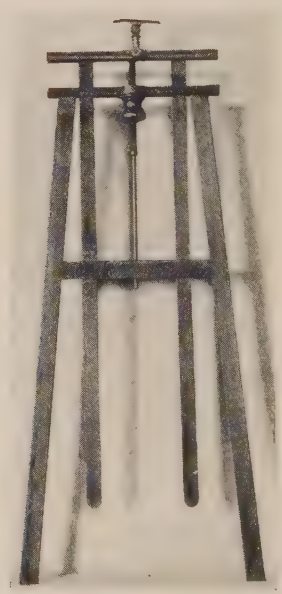
173. Two Square Oak Telescope Tubes. c. 1774.
Radcliffe Observatory.

A. 8-foot tube, 3 inches square, for $2\frac{1}{4}$-inch objective. Interior octagonal.

B. 2-draw 7-foot tube, $3\frac{1}{2}$ inches square for $2\frac{1}{2}$-inch object glass of 13 feet focal length. Also a 5 feet 4 inches extension tube, making a total tube length of 18 feet 6 inches.

174. Telescope Stand. c. 1774.
Radcliffe Observatory.

Mahogany. 3-draw, triangular section, with brass pivot at top.



No. 175. Telescope Support.
Radcliffe Observatory.

175. Mahogany Support for Telescope. c. 1774.
Radcliffe Observatory.

With altitude screw and azimuth rack.

Both stands are reminiscent of Hevel's stands (1673)

NO. 202. 8-FOOT TRANSIT BY J. BIRD, 1773

NO. 176. PART OF THE 5-FOOT EQUATORIAL SECTOR BY I. BIRD

The Declination and R. A. circles have been removed

Radcliffe Observatory

(*Machina coelestis*, pl. x). A similar device is figured in the *Hist. Coel.*, as in use at Greenwich in Flamsteed's time. Cf. fig. in Maunder's *R. Observ. Greenwich.*

Equatorial Telescopes

An Equatorial Telescope was described by Short in the Philosophical Transactions for 1749, the novelty of which consisted in the large size of the instrument. An Equatorial of about 2½ inches aperture was in course of construction by Bird when he died, but it was probably never finished.

176. 5-foot Equatorial Sector. 1774.

Radcliffe Observatory.

By Bird.

The arc has a radius of 5 feet, and is divided from 74 to ⟨90⟩ and 0 to 14. The telescope of 2½ in. aperture is about 5 ft. 5 in. in length. The declination and R.A. circles are 3 ft. in diameter. It was mounted under a Revolving Dome (Johnson). *See* pp. 320 and 336.

177. 10-foot Equatorial. c. 1795.

Radcliffe Observatory.

A letter from J. F. W. Herschel 27 July ⟨17⟩95 refers to it as 'recently mounted'.

The lens of 7-inch aperture was fitted to the new 24-inch photographic refractor in 1915, for use as a a finder.

ACHROMATIC TELESCOPES

Achromatic Telescopes were first constructed by a country gentleman of Essex, Mr. Chester Moor Hall, as early as 1733[1]; but as he was held by a court of law to have 'locked his invention in his scrutoire', patent rights were granted to John Dollond[2] who had independently arrived at a similar discovery and 'had brought it forth for the benefit of mankind'.

John Dollond's son Peter devised the triple object glass in 1765, and since that time the optical principle of the Refracting Telescope has remained practically unchanged to the present time.

[1] Trial of Watkins *v.* Dollond. *Gentleman's Magazine*, 1790, p. 890.

[2] *Phil. Trans.*, 1756, p. 733.

178. $3\frac{5}{8}$-inch Achromatic Telescope 4 foot focus. c. 1770.
By Dollond.

Christ Church.

Inner lens of doublet broken. The round mahogany tube is inscribed:

D.D.
Joannes Tunnadine LL.D.
et voluit nomen desideratissimi Juvenis
EDVARDI TAYLOR
Privigni sui una inscribi
ut simul Publicae Utilitati
simul Pietatis Officio
consuleret.

Peter Dollond's first triplets were made in 1765. This instrument must have been presented to the House after 1768, when Edward Taylor matriculated.

179, 180. 3-inch Achromatic Object Glasses. 1771–2.

Radcliffe Observatory.

By Dollond for Bird's Quadrants, Nos. 199 (see p. 321) and 200 (see p. 323).

Part of a transit instrument of the same date, inscribed 'J. Ramsden, made for A. Cumming 1772' is preserved in the Museum of the Clockmakers' Company in the Guildhall.

181. 4-inch Achromatic Telescope. 17—.

Queen's College.

By Dollond, *c.* 3 ft. 6 in. focus.

In a round mahogany tube, mounted on a light mahogany tripod stand.

182. $4\frac{1}{2}$-inch Achromatic Telescope. $10\frac{1}{2}$ foot focal length.

1774.

Radcliffe Observatory.

By P. and J. Dollond, whose bill is printed on p. 396.

Mahogany tube, $4\frac{3}{4}$ inches square, with two brass bands for support. Inscribed on eyepiece-fitting

DOLLOND, LONDON, 1774.

183. $3\frac{3}{4}$-inch Achromatic Telescope. 1774.
Radcliffe Observatory.

By P. and J. Dollond. See p. 396.

$3\frac{1}{2}$ foot focal length, in box. The triplet object-glass was broken, when the whole instrument was knocked over by the wind banging the observatory door, as Stone was setting out with it for Nova Zembla to observe the Total Eclipse of the Sun in 1896.

184. $2\frac{1}{4}$-inch Achromatic Telescope. 17—.
Radcliffe Observatory.

By Ramsden.

Tube 2 feet 6 inches long. In box; no stand.

185. $2\frac{1}{8}$-inch Achromatic Telescope. 2 foot focal length. 18—.
Radcliffe Observatory.

By Troughton & Simms.

Possibly used as a finder.

186. 6-foot Achromatic Telescope. 1836.
Radcliffe Observatory.

By Jones, mounted on a Meridian Circle. *See* p. 326.

187. $3\frac{1}{4}$-inch Achromatic Telescope. c. 1840.
Radcliffe Observatory.

By Tulley, London. 4 foot focal length.

The exquisitely perfect object Glass
of this Telescope was presented to the
Marquis of Blandford on his
Marchioness's Birthday in the year
1844
by his sincere Friend James South.

THIS VALUED INSTRUMENT GIVEN TO JOHN WINSTON 7TH DUKE OF MARLBOROUGH BY SIR JAMES SOUTH F.R.S. IS PRESENTED TO THE RADCLIFFE OBSERVATORY BY FRANCES ANNE DOWAGER DUCHESS OF MARLBOROUGH TO AID THOSE ASTRONOMICAL STUDIES IN WHICH HER BELOVED HUSBAND TOOK SO DEEP AN INTEREST AND TO PRESERVE A MEMORY OF HIM IN AN INSTITUTION OF WHICH HE WAS SO LONG TRUSTEE, NOVEMBER 1884.

Sir James South presented an achromatic object glass of 7·1 inches in diameter to the Duke of Wellington in 1834. It was ground in England from Guinand's glass.

REFLECTING TELESCOPES

In 1663 GREGORY proposed his 'Cata-Dioptrical Telescope' (*Optica Pronota*), but owing to his want of skill in the polishing of specula, his own instruments did not achieve much success. One of his specula was ground by 'Rives and Cox, two Optick glass grinders of London famous in those days' (Stone's *Suppl. to Bion*, p. 296).

The first persons to bring Reflectors into general use are said to have been Scarlett and Hearne, the opticians; but the art was not brought to its greatest perfection before JAMES SHORT in 1732, at the age of 22, began the grinding and polishing of specula.

The fine example of his work belonging to the Radcliffe Trustees has been dismounted.

188. Gregorian Reflecting Telescope. 2 inches aperture.

c. 1710.

Orrery Collection, 12.

This instrument is perhaps the oldest known example of the telescope invented by our Savilian Professor Dr. JAMES GREGORY and improved by HADLEY.[1]

The brass mounting with a double knuckle joint is screwed horizontally into a wooden pillar stand which is identical with that figured in Smith's *Optics*, p. 368, pl. 54; and in Harris's *Lexicon*. As originally sold, these instruments were accompanied by a small hand-auger for boring a hole in the side of a post or tree, for supporting the telescope 'when used abroad'. The brass tube has lost its original shagreen covering. It measures 16 inches in length.

189. Gregorian Reflector. 1742.

1 foot 6 inches diameter, and 12 foot focus.

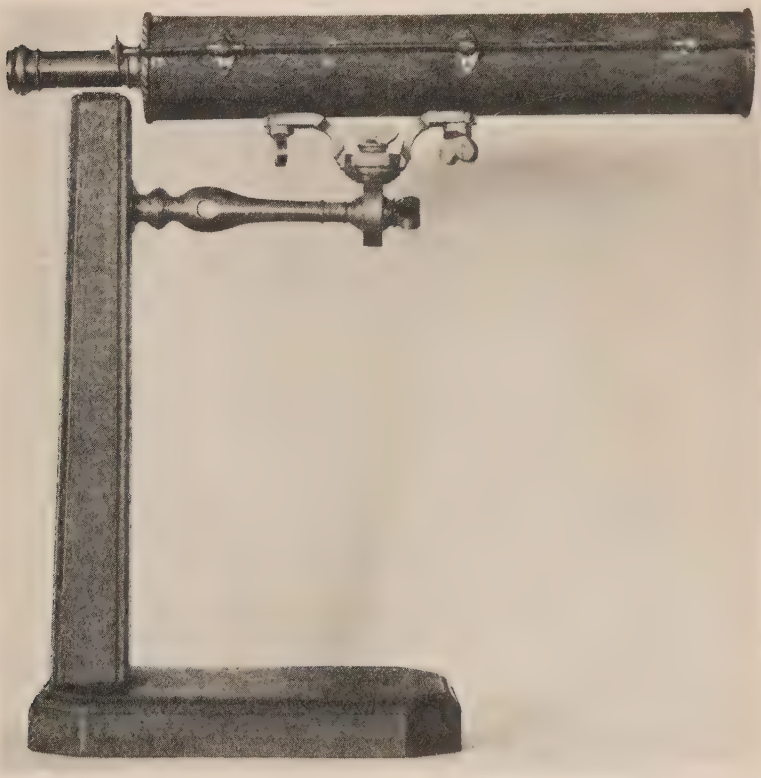
[1] James Gregory's Reflecting Telescope is described in detail in Desaguliers' *Appendix* to the 2nd edition of Dr. David Gregory's *Elements of Catoptricks and Dioptricks*.

NO. 192 NO. 182 NO. 183

Inscribed IAMES SHORT, LONDON, FECIT. No. 1. 144 1742. Repair'd by Thomas Short his brother 1770.

Box with 3 eyepieces and 2 flats.

The mirror of this instrument was unhappily left



No. 188. LORD ORRERY'S GREGORIAN REFLECTOR.
Christ Church.

exposed to the weather,[1] and its surface is utterly ruined. It is a great pity, because the perfection of Short's polishing was wonderful. The late Sir William Huggins had a six-inch mirror, figured by Short about 1760 or 1770, which still retained its original brightness in 1910.

[1] In 1882.

36-inch Reflector by Short.

Royal Society.

With an object glass micrometer by Dollond.

Used for observing Transits of Venus.

190. 4-inch Gregorian Reflector. ? 1750.

Magdalen College.

Pres. by Richard Persehowse, M.A., 1755.

191. 4-inch Gregorian Reflector.

Queen's College.

Both the Gregorian and Newtonian telescopes had been left imperfect by their inventors. It remained for JOHN HADLEY in 1719-20 to improve their work. The first reflecting telescope that he made with the assistance of his two brothers George,[1] the meteorologist of Pembroke College, and Henry, was bequeathed by the Rev. Hadley Cox, his nephew, vicar of Flitton, Beds., to his son in 1782 (*D. N. B.*). His first large reflector was shown on 12 Jan. 1781 to the Royal Society who 'ordered their hearty thanks to be recorded', and state in their journals that 'the force (of the telescope) was such as to enlarge an object near two hundred times, though the length thereof scarcely exceeds six feet'.

Dr. Bradley reported that with it he had seen 'the transits of Jupiter's Satellites and their shadows over the disc, the black list in Saturn's ring, and the edge of the shadow of Saturn cast on the ring . . . also several times the five satellites of Saturn'. Dr. Halley also tested it, and its performance in Hadley's own hands is described in the *Philosophical Transactions*, xxxii, p. 384.

Dr. Bradley also acquired a taste for mirror figuring and the combined efforts of the amateurs of the period resulted in the regular production of reflecting telescopes by opticians (*D. N. B.*).

Newtonian Reflecting Telescope. 1671.

Made by Sir ISAAC NEWTON.

Presented by Messrs. Heath & Wing, Math. Instr. Makers, Strand, London, on 6 Feb., 1766, to the Royal Society.

[1] Geo. Hadley, died 1768. The diameter of mirror of John Hadley's Reflector was 6 inches; its focal length over 5 feet 2 inches.

This little instrument is described in the *Philosophical Transactions* (No. 80), vii, p. 4004. It was the worst of two that Newton made, and was for some time to be seen at Mr. Heath's shop in the Strand.[1]

A contemporary Oxford opinion of this instrument is interesting.

The Savilian Professor characteristically did not think very highly of this Cambridge production. Uffenbach reports in his Diary that—

> 'He (Professor Carswell) did not approve Newton's invention of the small telescope, because the metal mirror was too liable to rust. When my brother (who had been taking lessons in lens grinding from Marshall) asked, whether glass mirrors would not serve the turn, he replied, that they absorbed too many rays. . . .'[2]

192. 8-inch Newtonian. 10 feet focal length. 1812.
Radcliffe Observatory.

By Sir Wm. Herschel.

It was ordered from Dr. Herschel in the summer of 1812 and was erected in April 1813; Sir William himself having come to Oxford to superintend the mounting and the adjustments of the mirror. It cost 300 guineas and Dr. Robertson, who was then Radcliffe Observer, conducted the correspondence. The Duke of Marlborough owned a similar one at Blenheim.

193. 13-inch Newtonian. 10 feet focal length. 1834.
University Observatory.

By Warren de la Rue, and improved by Troughton & Simms.

This instrument was made for Warren de la Rue's observatory at Canford and was presented to the University in 1873. It is still in its original state, with the exception of an addition of an electrical control to the driving clock in 1870. There are 2 specula and two silver-on-glass mirrors, refigured by With in 1879.

194. Broken Equatorial Tube. 7 inches diameter. 18—.
Radcliffe Observatory.

[1] Stone, *Suppl. to Bion*, p. 298.
[2] Uffenbach, 6 Oct. 1710. Cf. Marshall's advertisement, p. 298.

Astronomical Measuring Instruments with Telescopes

Quadrant. 1755.

Hornsby has left a note of observations 'made with my moveable Brass Quadrant, fitted up in a New Room with a new Limb, Nonius etc. accurately divided by Mr. John Bird in the Strand, London in 1755'.

195. 32-inch Mural Quadrant. 1767.
Radcliffe Observatory.

Signed J. Bird, London.

The telescope has an aperture of $1\frac{1}{4}$ inch, and is 3 ft. 2 in. long.

Constructed at a cost of £80 for Hornsby, who made his first determination of the latitude of Oxford, 51° 45′ 15″, with this instrument (*Phil. Trans.* lix).

Bird, the maker, wrote a letter relative to the accuracy of the 90 and 96 arch circles on 10 Oct. 1767.

196. 43-inch Transit. Aperture $1\frac{1}{2}$ inch. 1760.
Radcliffe Observatory.

Signed J. Bird.

The axis is 2 ft. long. This instrument was used by Hornsby in the West Wing of the Observatory. The Transit of Venus of 1769 was observed with it in the Schools.

12-inch Quadrant. Before 1769.
Royal Society.

By Bird. *Phil. Trans.* lix, p. 272.

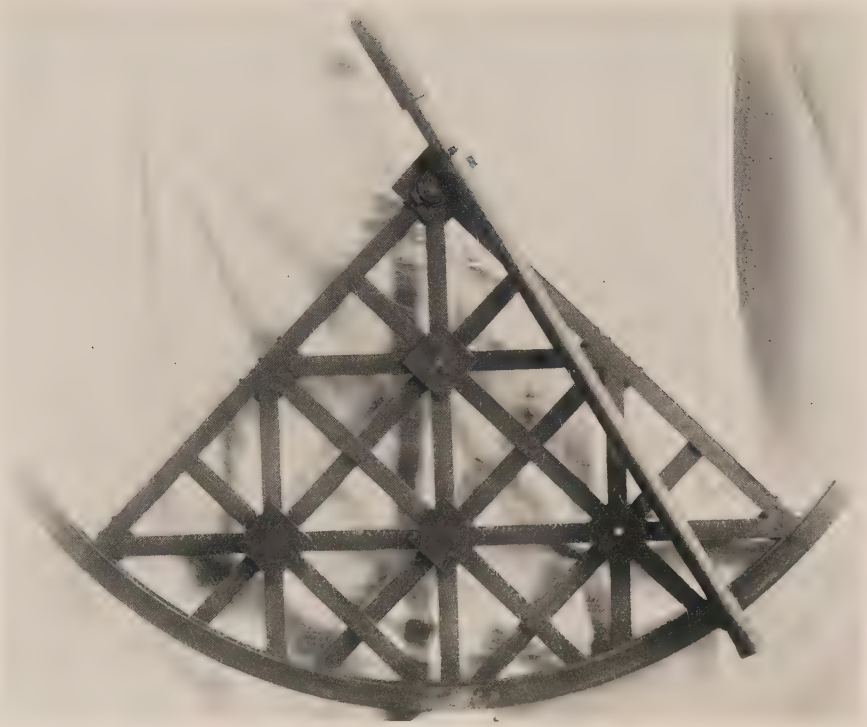
Used by W. Bayly for measuring zenith distances on Transit of Venus expedition at the North Cape in 1769.

12-inch Quadrant. 17—.
Royal Society.

By Bird, and redivided by Troughton.

8-foot Quadrant. 1770.

By Sisson, for George III's private observatory at Kew in 1770: deposited by H.M. Queen Victoria in the South Kensington Museum.



NO. 195. HORNSBY'S 32-INCH MURAL QUADRANT AND 43-INCH TRANSIT, 1760. BY J. BIRD

Radcliffe Observatory

12-inch Quadrant. c. 1767.

South Kensington Museum.

By Bird. Lent by R. J. Lecky, F.R.A.S.

Used by Capt. Cook during his Voyages, and mentioned in the *Philosophical Transactions*, lxix, p. 164.

'The vertical axis is on a pedestal, standing on four levelling screws. There is a horizontal circle of $4\frac{1}{2}$ in. diam. with slow motion screw and vernier. Attached to the frame is a spirit level for approximate levelling. For more accurate adjustment, cage plummets, suspended by silver wires in tumblers of water are used. The vertical limb of 1 ft. radius is divided into 90° in the ordinary way, and into 96 parts, according to Bird's method, with a supplementary arc of 16° at each end of the limb. A slow motion screw and verniers for both sets of divisions are fitted to the telescope, which is a reflector, and fitted with cross wires. A refracting telescope for observing horizontal angles is fixed to the top of the frame.'

The Radcliffe Observatory Instruments. 1772–3.

Radcliffe Observatory.

By Bird and Dollond.

Bird had written a paper *On the Method of constructing Mural Quadrants*, which was published in 1768 by order of the Commissioners of Longitude.

The Radcliffe Trustees were very fortunate in being able to secure the services of Bird for the construction of a set of instruments which in precision and power excelled all others of that day. The order was only given just in time, for Bird was expecting orders for other instruments from the Astronomer Royal, and his bad health set limits to his powers of performance. Indeed, he died on 31 March, 1776.

Hornsby was the first person who could induce Bird to use achromatic object glasses, against which he had taken up an extraordinary prejudice,[1] but this was eventually overcome and on 29 Jan. 1771 Bird wrote to Professor Hornsby

'. . . I called upon Mr. Dollond on my way home, and enquired about the expense of the glasses. Two at 3″ diam. will be 4 guineas each set, and for the Transit instru-

[1] Ingram, *Memorials*, Note to p. 7.

ment at 12 guineas, if of a proper diameter for a focus of 8 ft. This will require a weighty tube and therefore a very strong axis, which altogether will be too heavy for two men to turn end for end, with safety, but I can make an apparatus with which it may be turned by a boy of 12 years and without danger.

The telescopes for the Quadrants will be larger than at Greenwich. Estimate:

	£
2 Quadrants of 8 ft. each £380	760
Transit	150
	£910

exclusive of packing and wooden house for graduation.

12 ft. Zenith Sector £150.

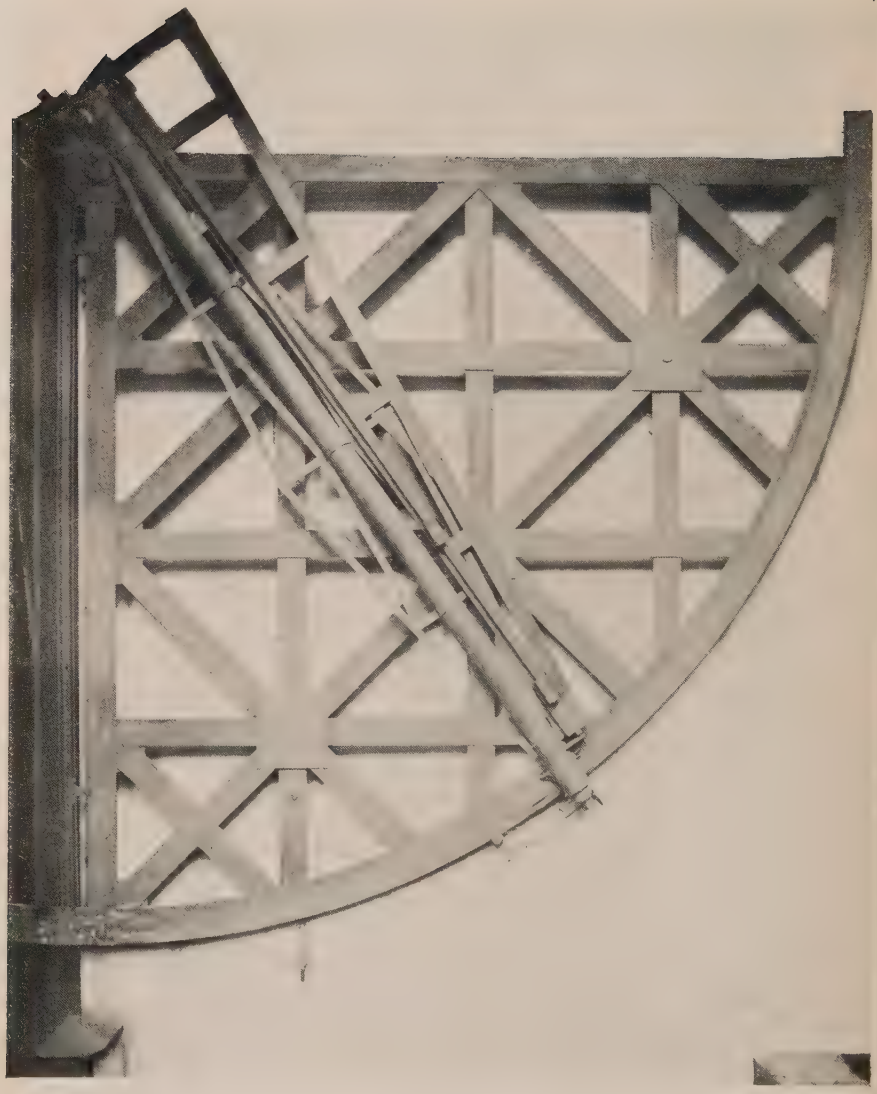
Equatorial with 5 ft. Dollond Telescope and 3 ft. circles, such as the Astronomer Royal is about. £200.

N.B. Unless you determine soon the Astronomer Royal will be before you.'

Hornsby, on receipt of further financial details on 2 Feb. 1771, immediately placed his order and on the 9th Feb. received Bird's acceptance. 'You have given your orders for the instruments just in time, for I expect the Astronomer Royal every day to order an Equatorial Sector.' 'It will not be your interest to limit me in time, my intention is to do the best in my power, therefore must not be hurried. I may be hindered by neglect of workmen, or my disorder. . . . I believe I can still enlarge my place in Berwick Street at a small expence' (16 Feb. 1771). 'I can have no chance of getting money for anything else, for the reason that I mentioned in my last. Your instruments will be in the way of everything else' (*Letter* of Bird 18 Feb. 1771).

On 20 Feb. the articles of agreement between the University and Mr. Bird were approved and were finally signed on March 20th; Professor Hornsby at the same time promised to inform the Board of the progress of the instruments.

The size of the instruments was limited by the Object Glasses that were previously to be ground by Dollond. The progress made in their construction was chronicled



NO. 199. SOUTH MURAL QUADRANT BY J. BIRD, 1772

Radcliffe Observatory

in terminal reports by Hornsby, and will be stated in the sections dealing with the separate instruments, but it should be mentioned here that at the beginning of the Michaelmas term, Bird wrote, 'I am resolved that no persuasions whatever shall interrupt the progress of your instruments, therefore pray make yourself quite easy and me not uneasy upon that head. This winter is a proper time to prepare the stones, which if neglected I believe the buildings will not be finished as soon as will the instruments.' (*Letter* of 22 Oct. 1771.)

The financial arrangements were rather indirect because neither the University nor the Radcliffe Trustees had in hand so large a sum of money as that required. It was therefore settled that the money due to Bird should be advanced out of the profits of the Clarendon Press and should be subsequently refunded by the Trustees. The account was as follows:

Sums paid from Press funds.			Paid by Radcliffe Trustees.	
1771	Bird.	£300		
1772	,,	230		
1773	,,	400		
1774	,,	200		
	Hornsby for carriage	41. 12.		
1775	Bird.	100		
	For carriage.	17. 5.	1780	£500
1777	Exors.		1781	£500
	of Bird.	103. 19.	1782	£392. 16.
		£1392. 16.		£1392. 16.

199. 8-foot South Mural Quadrant. 1772.

Radcliffe Observatory.

By Bird.

Bird's large quadrants are similar in many respects to the other large quadrants made by Sisson for the private observatory of George III at Kew[1] in 1770, and for the observatories of Paris and Greenwich, earlier in the century, from the directions of Graham.

[1] In 1842 the Kew Observatory was handed over by the Crown to the British Association for the Advancement of Science and most of its contents were dispersed.

The arc is graduated in divisions of two minutes. The telescope, which was attached to a brass[1] lattice-work frame, to prevent flexure, carried a 3-inch object glass, having a focal length of 8 feet. To facilitate manipulation the telescope was connected with a counterpoise by means of a cranked lever and a firm wood frame. The arm, which joined the counterpoise on one side and the telescope on the other, passed a little above the centre of the quadrant through a gap in the wall, to which the instrument was attached. Small rollers near the eyepiece of the telescope reduced friction on the limb; a clamp fastened the instrument in any position, and a vernier served to read to fractions of the scale of the arc.

The size of the instruments was determined by that of the Object Glasses, which were finished by Peter Dollond in July 1771 at a contract price of 4 guineas a set. The telescopes were 8 feet long and showed a magnification of 60 diameters.

Bird found great difficulty in procuring suitable bars of brass for the construction of these quadrants. The brass had to be cast of a certain length and thickness, and then rolled into plates or bars of the proper size. No English manufacturer could be found who could roll a plate for the base of a greater length than 6 feet, so that Bird was compelled to send an order to Holland for the 8-foot lengths he required. The Dutch firm, however, seemed so dilatory in the execution of the order, that Bird was on the point of accepting the shorter 6-foot bars from Cheshire, and by soldering them together to make the 8-foot bars required. Fortunately, however, the bars arrived from Holland in time, and being found to be quite satisfactory, Bird increased the number of his workmen, and by 9 March, 1772, the whole quadrant had been planed and filed for the first framing. Two thousand screws were turned, 420 steady pins were made, collars of cast steel round which the telescopes move, of excellent workmanship, were received from Sheffield, and the telescopes were approaching completion.

[1] The frame of the Greenwich Quadrant was made of straight iron bars, measuring in section $2\frac{9}{10}$ in. by $\frac{1}{5}$ in., but the limb was overlaid by the brass arch which was graduated by George Graham himself.

In April the quadrants were removed from the Strand to a small wooden house specially erected in Little Marylebone Street at a cost of £51 3*s.* 6*d.* (May 13, 1772), to be divided during the summer months, at the time of year when only that part of the work and the most essential to the accuracy of the instrument can be executed. On 5 May Bird reported, 'I have now laid the foundation of the first quadrant and except some cocks (the patterns of which could not be made till the draught was drawn) all the parts are ready for putting together. I hope to have almost a thousand screws in it when you come next to town.' On 3 June Hornsby saw one of the quadrants almost ready for dividing, and reported that Bird was proposing to start dividing on 29 June and that his health was much improved by the move from the Strand.

Bird's Mural Quadrants were built on the pattern of Graham's. The division of the circle was effected thus: the radius gave the 60°, which was halved, 30°, and the distance measured by a beam compass to the 60°, gave the 90° mark. Each 30° was then bisected. Thus far Bird followed Graham's method, but once having found 75°, he by the calculated sines of 10° 20′ and 4° 40′, obtained the point 85° 20′ (= 75° + 10° 20′ or 90° − 4° 40′), and then this arc of 2 5 he subdivided by repeated bisections into 5′ intervals.

Hornsby appears to have examined the instrument critically in August, and to have found the divisions more accurate than he expected. It was completely finished in September, carefully packed up in very strong boxes, and removed to a convenient wharf below Westminster Bridge where it remained until it could be put on a barge for Oxford. Bird wrote that 'as it is made with greater solidity and with more improvements than any other hitherto made, I scruple not to call it by far the best instrument of the kind in the world'. (23 October, 1772.)

200. 8-foot North Mural Quadrant. 3-inch aperture.

1773.

Radcliffe Observatory.

By Bird.

The framing of the second Quadrant was commenced

on about the 20 March, 1773, and great progress had been made with it by the end of the first week in May.

201. 12-foot Zenith Sector. $3\frac{1}{2}$-inch aperture. **1773.**
Radcliffe Observatory.

Radius 11 feet 8 inches.

By Bird.

202. 8-foot Transit. 4-inch aperture. **1773.**
Radcliffe Observatory.

By Bird: the object glass by Dollond: magnifying power of the eyepiece 110.

The Transit Instrument and Zenith Sector appear to have been in hand at about the same time. On 24 October, 1771, the object glass was very nearly completed; the cross axis, supports, apparatus for the level, and the arch for the divisions were finished; the eyeglasses and brass tube for the telescope were expected to be ready in about a fortnight, and the apparatus for lifting the whole instrument was in hand.

The Transit was practically complete by the end of 1772, but the graduation of the arch could not be begun before the warm weather: it was, however, completed by 7 May, 1773, when both Transit and Zenith Sector were finished and packed for water-carriage to Oxford.

Bird died on the 31 March, 1776.[1]

In 1840 Johnson reported that the objective 'gives a remarkably neat and well-defined image'.

The tube of the telescope is composed of four cylindrical pieces attached to a cubical centre-piece. The Horizontal

[1] My friend Professor H. Turner has drawn my attention to a beautiful mezzotint engraving of Bird by N. Green, after a painting by Lewis, published nine months after Bird's death in 1776. It is inscribed

JOHN BIRD OF LONDON

Who furnished the Chief Observatories of the World, with the most capital Astronomical Instruments, divided by him after an improved method of his own, in a manner superior to any executed before, for which, and many other Improvements in the Construction of Astronomical Instruments, he was honoured with a considerable Recompense from the Commissioners of Longitude.

He is seated at a table on which lie the working drawing of a Quadrant and the Beam Compasses which he used for dividing the arcs.

NO. 201. ZENITH SECTOR AND OBSERVING CHAIR

Radcliffe Observatory

Axis is 3 ft. 10 in. The Pivots are 1·6 in. in diameter, and 2·5 in. long, of which 0·6 in. only rests on the nearly rectangular Y's; the remaining portion was left for receiving the Index of the Setting Circle, and the rods for connecting the Axis with the Counterpoises. But the original Setting Circle has been replaced by Circles at the Eye-end, and for some time no use has been made of the Counterpoises. They are in construction precisely similar to those generally applied to German Instruments. Upright bars of iron 18 in. long, cased in mahogany, are firmly fixed to the tops of the piers; the bars terminate at the upper end, in knife edges, which form the fulcra of wooden beams, from one extremity of which hang the counterpoises, and from the other flat rods of wood with triangular bearings at the bottom to receive the pivots.

The Piers are of Bath freestone. They are 7 ft. 6 in. high above the floor, 2 ft. 2 in. thick in the direction of the meridian, and in a 3–2 direction they are 2 ft. 8 in. at the base and 2 ft. 2 in. at the top. They stand on a mass of concrete, laid on the natural gravel.

On Jan. 31, 1834, a new level was placed on the axis by Mr. Jones of Charing Cross, who in 1836 adjusted it.

In 1839, on Dec. 24, the Transit was removed by Johnson from the E. Wing to the New Room in the W. Wing and placed on its piers.

Micrometer: In April 1840 spider's web lines were substituted for the older metallic wires.

Level Error: The solid pivot is larger than the perforated one.

Collimation: Two lenses, one of 300 ft. focal length and the other of 180 ft., fixed to stone slabs in N. & S. walls and two marks were erected on the boundary walls of the Observatory enclosure, in respective foci, in July 1840 by Jones. In 1840, Jan. 7–16, Jones fitted a new micrometer eyepiece to the telescope and added the small Setting Circles.

Also see No. 204.

42-inch Transit. **Older than 1819.**
Royal Society.

By Dollond.
Used by Capt. Kater. *Phil. Trans.*, 1819.

27-inch Transit. **1834.**
Royal Society.

203. 6-foot Meridian Circle, 4·1 inch aperture. **1836.**
Radcliffe Observatory.

By Thomas Jones of Charing Cross. In use until 1861.

Erected during the time of Johnson in extreme W. Room, which had previously been occupied by the small transit, No. 196.

It differs in construction from the Mural Circle in being supported on both sides of the graduated Circle. It revolves on two pivots of equal diameters. The one on the E. side is placed within a few inches of the graduated Circle; that on the W. side at the extremity of a large cone, 2 feet 6 inches long, projecting from the centre piece of the Circle; through this, the illumination is conveyed to the wires. Both pivots rest on Y's attached to stone piers. The Reading Microscopes are attached to the outer edge of the E. pier, and are directed towards the graduations of the Circle. In several respects the Instrument resembles the Armagh Circle described by Dr. Robinson (*Mem. R. A. S.* x).

Circle divisions are 5 feet apart. The telescope is securely held between the graduated circle and another parallel to it. The two circles are bound together by stiff braces at short intervals from each other, and the alternate braces are supported by conical radii proceeding from the centre piece. This construction is believed to have been designed by Mr. Pond with the view to making the instrument efficient as a Right Ascension Instrument (Johnson, *Radcliffe Astr. Obs.*, 1840).

The method of suspending the chain was altered by Jones in March 1840.

204. Transit Instrument. **Oct. 28, 1843.**
Radcliffe Observatory.

Although re-entered here under a new number, this instrument is in part No. 202, remodelled by Simms in 1843, after it had been in use for sixty-nine years. The following is Mr. Simms's account of his work.

'In remodelling the Transit Instrument, which has now a form more consistent with strength and beauty than it formerly had, the Object Glass, Setting Circles, Micrometer, and Axis Level, of the former Instrument were made use of.

NO. 203. MERIDIAN CIRCLE BY T. JONES, 1836

Radcliffe Observatory

'The Axis consists as usual of three parts; the Central Zone and two Cones, each of the latter terminating in a Cylindrical pivot of hard bell metal.

'The Zone was cast with flanges at each side, leaving an aperture of about 8 inches in diameter. The flanges are pierced at intervals with holes slightly enlarged towards the inside. From the bases of the Cones there are projecting necks corresponding in number and position to the holes in the flanges, and so exactly regulated as to size, that when once the necks are inserted, the parts, under a common temperature, are inseparable; besides this connection, there are 28 screws passing through, from the interior of the Zone into the bases of the Cones.

'In order to put the Axis together, the Zone was heated, and when the holes in the flanges were sufficiently enlarged, the necks were introduced, and the screws inserted. The contraction of the holes in cooling soon caused them to lay hold of the necks, the screws were then driven home, and a steady pin passed through each of the heads to prevent the possibility of their ever becoming loose.

'The Axis was finally put into a lathe between dead Centres, and the last touch given to the Pivots with the point of a diamond.

'The Telescope consists of two *frusta* of Cones, the bases being screwed to the Zone by screws from within. There are also four tension rods which serve as auxiliaries for drawing the Telescope tubes firmly down upon the Zone, and also carry the frame by which the diagonal Illuminator is supported.

'The amount of light admitted to the field of the Telescope is regulated by altering the Angle of the Reflector, which can be readily done by turning a milled-head placed so near the eye-end of the Telescope as to be at all times under the immediate command of the Observer.'

To this account Manuel Johnson adds: 'The length of the horizontal Axis, exclusive of the pivots, is 3 feet. The pivots are 2 inches in diameter, and $2\frac{1}{2}$ inches in length; of this only one inch rests in the Y's, the remaining portion, next to the Axis, being left, in case it should be found advisable at any time to use counterpoises, which has not been done hitherto.

'The Y plates are those of the old Instrument, and I believe cannot be improved; stiff iron rods are fixed to the back of them, terminating with screws, which pass through the piers, and the plates are drawn close upon the face of the pier by nuts working upon the screws of the iron rods. Besides this, they are secured by 4 screws in front. The Y's have the

usual adjustments, for Level and Azimuth, which are communicated by single screws. The only alteration necessary to be made in the Piers was to bring the upper stones a little forwarder on account of the diminished Axis.

'The Instrument was erected under Mr. Simms's immediate direction, and in justice to him I must remark, that in point of stability it has exceeded my expectations. I am writing after 16 months' experience of it, and it was during the last fortnight that I had occasion for the first time to touch a single adjusting screw; till that time, the Instrument had kept its adjustments within very small limits.'

(*Radcliffe Obs. Report*, 1843.)

A meridian mark was fixed on the north wall of Worcester College at a distance of about 682 yards to the south of the instrument. When the central tower of the observatory was being built, the increasing weight caused the western pier to sink more than the eastern pier and by which the Axis was tilted 3″. (Hornsby, quoted by Rambaut, *Monthly Notices R. A. S.* 1900, p. 267.)

This instrument was used for determining Right Ascensions, in conjunction with Jones's Meridian Circle of 1836, until the death of Manuel Johnson. It was superseded by the new Transit Circle by Troughton and Simms, with a 5-inch object-glass purchased by R. Main.

205. Transit Circle. **1846.**

University Observatory.

By Troughton and Simms.

The original telescope 4 inch aperture, 4 feet 4 inches focal length, came from Mr. J. Gurney Barclay's observatory at Leyton, and was offered to, and set up in, the University Observatory in 1887.

Savery's Heliometer. **27 Oct. 1743.**

The basic idea of a telescope with two object glasses, which could be moved nearer or farther from one another, appears to have been due to Römer as early as 1675, but it was not reduced to practice before a paper on the subject was sent to Martin Folkes, President of the Royal Society, by SERVINGTON SAVERY on 27 Oct. 1743. It was entitled *A new way of measuring the Difference between the apparent Diameter of the Sun at the Times*

NO. 202. 8-FOOT TRANSIT BY J. BIRD (REMOUNTED)

Radcliffe Observatory

NO. 206. SAVERY'S OR DOLLOND'S HELIOMETER, C 1755

Mineralogical Department

of the Earth's Perihelion and Aphelion, with a Micrometer placed in a Telescope invented for that purpose, tho' the Charge or magnifying Power of the Telescope is so great, that the whole Sun's Diameter does not appear therein at one View.

Although Savery also wrote to George Graham on the same subject on November 1st, his paper was shelved and forgotten, until in 1753, James Short, who was interested in auxiliary apparatus for Gregorian Telescopes, once more reminded the Royal Society of a Paper of the late Servington Savery, Esq., relating to his invention of a new Micrometer. The Invention was then published with full particulars, and the instrument was constructed by John Dollond in or shortly before 1755, and was figured in Lalande's *Astronomie.*

In the meantime a Frenchman, Pierre Bouguer (1698-1758), had in 1747 constructed a Heliometer on the same principle, and is generally given the credit due to a first inventor.

However, in December last year my friend Professor Bowman showed me an old instrument belonging to the Department of Mineralogy that was unfamiliar to him, but which I have now identified as an early form of Savery's Heliometer as constructed by John Dollond. This Oxford example interested me in the inventor, who is not mentioned in the *Dictionary of National Biography*, but whom I hope to have the pleasure of introducing to the editors of the new edition of that work as SERVINGTON SAVERY, a Demy of Magdalen College, who matriculated in 1704, aged 17, took his M.A. in 1711 and became Rector of Norton-sub-Hambdon, Somerset, in 1730. He may have inherited scientific tastes from his father, who was a Bachelor of Medicine.

206. Savery's Heliometer. c. 1755.

Bequeathed by Professor N. Story-Maskelyne to the Mineralogical Department.

Probably made by J. Dollond.

Fitted for use with a Gregorian Telescope of $4\frac{1}{2}$-inch aperture. Savery referred to his invention as a 'micrometer': the name 'héliomètre' was due to Bouguer.

Two of these Heliometers or 'Divided Object Glass Micro-

meters' by Dollond are in the S. Kensington Museum. One fitted for a $4\frac{3}{4}$-inch tube, was evidently used with the Gregorian Reflector by James Short, that belonged to the Royal Society, and was used on the Transit of Venus Expedition of 1769.

207. Heliometer. **1848.**

Radcliffe Observatory.

By Repsold and Merz of Hamburg.[1]

Dismounted *c.* 1905.

Bessel having been consulted by Sir Robert Peel, on behalf of the Radcliffe Trustees, as to what instrument added to the Radcliffe Observatory would probably most promote the advancement of astronomy, strongly advised the selection of a Heliometer. The order for the instrument was given to the Repsolds in 1840, but 'various circumstances, for which the makers are not responsible, contributed to delay the completion of the instrument, which was not delivered before the winter of 1848'.[2] The building to receive it was commenced in March 1849 and completed by the end of the same year. The instrument has a superb object glass of $7\frac{1}{2}$ inch aperture and 126 inches focal length. The makers availed themselves of Bessel's suggestion to make the segments move in cylindrical slides, and of Struve's to have the head attached to a brass tube; the eyepiece is set permanently in the axis, and the whole rotates in a cradle attached to the declination axis. They provided a splendid, rigidly mounted, equatorial stand, fitted with every luxury in the way of slow motion, and scales for measuring the displacement of the segments were read by powerful micrometers from the eye end. The illumination of these scales is interesting as being the first application of electricity to the illumination of astronomical instruments: a thin platinum wire was rendered incandescent by a voltaic current; a small incandescent electric lamp would now be found more satisfactory. It is somewhat curious that though Struve's second suggestion was adopted, his first was overlooked by the makers. But it is still more curious that it was not afterwards carried out, for the communication of auto-

[1] Georg Repsold 1804–1885, s. of J. G. Repsold 1770–1830: Georg Merz 1793–1867.

[2] Johnson, *Radcliffe Observatory*, 1850.

matic symmetrical motion to both segments only involves a simple alteration. But, as it came from the makers in 1849, the Oxford heliometer was incomparably the most powerful and perfect instrument in the world for the highest order of micrometric research. It so remained, unrivalled in every respect, until 1873.[1]

In 1880 the position circle was redivided by Simms.

At the present time the instrument is lying in pieces on the upper floor.

208. Universal Instrument. ? 184–.

Pritchard Collection. University Observatory.

By Dollond.

209. Floating Horizontal Collimator. c. 1830.

University Observatory.

By Troughton and Simms.

In the original 1824 pattern of Kater's horizontal collimator, the trough was rectangular. This instrument has the circular trough with central well, employed by Kater for his 1828 vertical collimator (*Phil. Trans.*, 1828). This instrument must date from *c.* 1830.

MAKERS OF REFLECTING TELESCOPES

James Gregory, 1638–75.

Educated at the Marischal College, Aberdeen. He invented his reflecting telescope in 1661, and described it in *Optica Pronota* in 1663. He went to London to order one from Reive[2] the optician, but the speculum proved so bad that the instrument was useless.

A serviceable instrument was presented to the Royal Society in 1674 by Robt. Hooke of Christ Church.

David Gregory, 1661–1708.

Son of David Gregory (1627–1720), the elder brother to James, was educated at the Marischal College and at Edinburgh University. Savilian Professor and F.R.S. 1692. His son David became Dean of

[1] *Ency. Brit.* 1910, Art. *Heliometer.*
[2] The name is spelt Reeve, Reive, and Rives.

Christ Church. A concluding remark in his *Catoptricae et Dioptricae Elementa* (Oxford, 1695), a text-book for his students, as to the possibility of counteracting colour-aberration in lenses, by combining in them media of different densities, gave the first hint of the achromatic telescope. (*D. N. B.*)

RIVES[1] and COX.

Speculum grinders for Gregory.

ISAAC NEWTON, *b.* 1642, *d.* 1727.

He constructed his first reflecting telescope in 1668, and sent his second to the Royal Society in 1671. (*Phil. Trans.* March 25, 1672.)

JAMES BRADLEY (*b.* 1692, *d.* 175-), of Balliol College, 1710–14.

Savilian Professor 1721. He attempted to make a Hadley Reflector about three years before Smith's *Optics* was printed, but had to stop owing to a change of residence. Bradley and Smith began to make reflectors of 26 inches focus and had one ready for use in May 1724. They then attempted one of 8 feet focal length.

FRANCIS HAWKSBEE of Crane Court.

The maker of a good reflector of $3\frac{1}{2}$ feet; he worked at others of 6 feet and 12 feet. He was living in Fleet Street in Wine-office-court in June 1710, when Uffenbach 'did not find him at home'.

SCARLETT & HEARN.

Opticians and mathematical instrument-makers of Dogwel Court, White Friars, who made reflectors on a commercial scale. They had been instructed in the art by Molyneux, who with Bradley had learnt speculum-polishing from Hadley.

JAMES SHORT, *b.* Edinburgh 1710, *d.* London 1768.

Educated for the Church, he commenced making Gregorian reflecting telescopes in 1732 in the rooms of the mathematical Professor Colin Maclaurin, who wrote, about 1734, that Short's telescopes with metal

[1] The name is spelt Reeve, Reive, and Rives.

specula 'far surpass those I have seen of any other workman' . . . 'He executes every part himself, and takes vast pains to make the instruments as perfect as possible.' They were made of 6 feet, 9 feet, 15 feet focal lengths.

WILLIAM HERSCHEL, 1738-1822.

A teacher of music at Bath, who commenced the making of specula in 1774, completed 400 specula by 1778, including a 7-foot reflector in 1775, a 10-foot in 1777, a 'very good 10 foot' in 1778, and with the aid of a grant of £2,000 from George III he completed a 40-foot in 1787.

MATTHEW LOFT.

A nicely finished small Gregorian Reflector of $2\frac{3}{4}$ inches aperture, marked 'Matthew Loft Fecit', is in the Physical Laboratory of the University of Nottingham. It is obviously a very early example. A later maker of a similar instrument was J. GILBERT, TOWER HILL, LONDON.

MAKERS OF REFRACTING TELESCOPES

LEONARD DIGGES, *c.* 1540.

HANS LIPPERSHEY of Middelburg, Holland.

Invented a refracting telescope with a concave object lens in 1608.

GALILEO, *b.* 1564, *d.* 1642.

Constructed in 1609 a refracting telescope with a concave eye-lens on Lippershey's model, which he publicly exhibited to the Senate in Venice, who in return gave him a professorship for life.

HEVELIUS of Danzig used a telescope of 140 feet.[1]

CONSTANTINE HUYGENS.

Private Secretary to King William III, made 'very good and long' telescopes of 12, 23, 30, and 123 feet.

[1] For accounts of contrivances for using long telescopes, see Hevelius, *Machina Coelestis*, and the works of Chérubin de la Hire, and Huygens, *Astroscopia*, Hague, 1684, translated in Smith's *Optics*, vol. ii.

He discovered a satellite of Saturn in 1655, and ground object glasses for his brother's telescopes.

BORELLI, 1608-79.

A pupil of Galileo, made telescopes of 40 and 70 feet which showed the two inner satellites of Saturn.

JOSEPH CAMPANI and EUSTACHIUS DIVINI of Rome.

Esteemed the best makers of telescopes in their day. They made instruments of 23, 24, 30, 33, 45, 50, 60, and 70 Roman palms. The longest Campani telescope of 150 Roman palms was used in 1725 by Francis Bianchini who had others of 70 and 100 Roman palms respectively. A Campani telescope of 35 feet showed the 3rd satellite of Saturn in 1672 and his 106 and 136 foot glasses showed 4 satellites in 1684.

Campani invented the erecting or terrestrial eyepiece with 4 lenses.

Eustachius Divini made an achromatic eyepiece of two plane-convex lenses, preferably with water between them.

Campani was followed by the Italian adapters of eyepieces:

ANTHONY MARIA DE REITA who made an eyepiece with 5 convex lenses.

FONTANA who made an eyepiece with 8 convex lenses. But 'objects appeared coloured so that tube could not be much used without injury to the eyes'.

EUSTACHIO of Naples who made an eyepiece with 19 convex lenses.

CASSINI of Bologna.

Maker of a telescope of 136 feet. In 1717 he observed the apparent diameter of Sirius.

ARTOUQUELLIUS.

Maker of telescopes of 80, 155, and 220 feet, the longest on record. *Phil. Trans.*, No. 92, 181.

PETRONI had a reputation for good telescopes about 1750.

JOHN MARSHALL, Perspective Maker, Ludgate Street.

The maker of the two vellum tube telescopes in the Orrery collection. On 27 June, 1710, he was visited by Uffenbach who described him as a 'famous glass grinder', whom Uffenbach's brother, 'with some pains, engaged to teach him the art'.

He appears to have been in partnership with Yarwell for a short time. *See also* pp. 298 and 306.

JOHN YARWELL, 1692.

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ALL the above-named Instruments as Telescopes of all Lengths, Microscopes Single and double, Perspectives great and small, Reading Glasses of all sizes, Magnifying Glasses, Multiplying Glasses, Triangular Prisms, Speaking Trumpets, Spectacles fitted to all Ages, and all other sorts of Glasses, both Concave and Convex are made and sold by JOHN YARWELL *at the* Archimedes *and* Three Golden Prospects, *near the great North Door* in S. Paul's *Church-Yard*: London.

[At the end of William Molyneux, *Dioptrica Nova* 1692.]

JAMES WILSON.

Maker of small pocket microscopes, at the Willow tree in Cross St. Hatton Garden 1702. *Phil. Trans.*, No. 281, p. 1241.

'I never met with anything like Mr. Wilson's glasses.' (Harris.) A telescope lens signed by him is in the Orrery Collection, p. 307.

MAKERS OF ACHROMATIC REFRACTING TELESCOPES

JOHN DOLLOND, 1706-61.

Huguenot silk weaver who studied optics and astronomy: in 1758 read a paper to the Royal Society on Refraction without colour.

A sextant by him belongs to Oriel College.

PETER DOLLOND, 1730–1820.

Set up as Optician in the Strand 1750, moved circ. 1752–3 to St. Paul's Churchyard, where he was helped by father, John, until 1761. Admitted brother JOHN

into partnership in 1766, replacing him, on death in 1804, by nephew GEORGE.

He made triplet lenses after 1765. *Phil. Trans.* lv, p. 54. His first were of $3\frac{3}{4}$-inch aperture and $3\frac{1}{2}$ feet focal length. Those that he made for Bird are in their original positions in the Radcliffe Observatory.

GEORGE ADAMS, 1750–95.

Of 60 Fleet St. in 1763. See vol. i, p. 185. Maker of an improved Equatorial *c.* 1785.

EDWARD TROUGHTON. See vol. i, p. 186.

EDWARD NAIRNE, 1761–1806.

See vol. i, p. 187. Maker of an Equatorial *c.* 1771.

THOMAS JONES, 1775–1852. See vol. i, p. 187.

Note on Bird's Equatorial Sector, p. 311

Since the preceding pages were in type, Mr. W. H. Robinson drew my attention to the following notes among the papers of the Radcliffe Observatory.

'I presume you are to have an equatorial Sector. Mr. Bird can acquaint you of the plan of one which I have settled with him of 5 feet radius. I suppose you will also have a Zenith Sector.' (*Letter* from N. Maskelyne to Hornsby, dated Greenwich, June 13, 1771.)

'The Equatorial Sector is not yet made, but the detached building which is to contain [it] is nearly finished. It is well calculated for the purpose, and is built upon the suggestion of the Bishop of Chester after the Temple of Romulus and Remus.' (*Draft of Letter* by Hornsby c. 1773, see p. 394. The building was built by Mr. Keene.)

'Mr. Bird died in 1776, before he had finished the equatorial: the consequence was that it never was good for much, and is now nearly useless.' (S. P. Rigaud, Sept. 10, 1830.)

APPENDICES

DESCRIPTIONS OF EARLY ASTRONOMICAL INSTRUMENTS

A. THE RECTANGULUS

By Richard of Wallingford, 1326

Printed from C. C. C. MS. No. 144, fol. 79. Collated by the Rev. H. Salter with MS. Digby 168, ff. 62v–64v, and MS. Laud Misc. 657, ff. 46–52.

See p. 32.

Prologus in artem componendi instrumentum rectanguli.

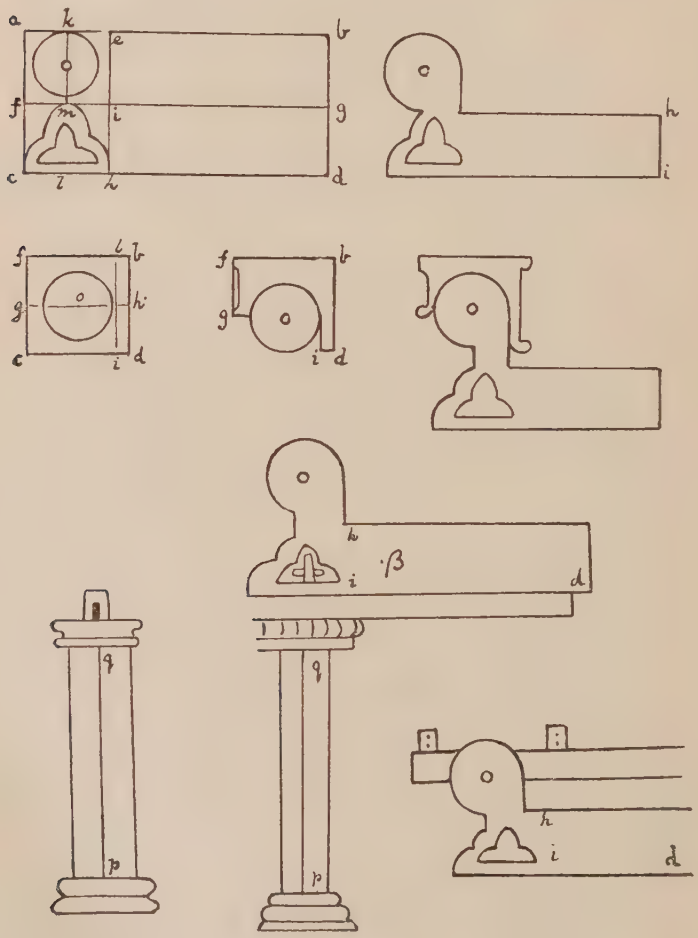
Rectangulum in remedium tediosi & difficilis operis armillarum eodem tempore quo composuimus Albyon, hoc est sub annis Cristi 1326, concepimus ad rectificandum cursus & loca stellarum errancium & fixarum, nodos eciam orbis novi existentes in ecliptica apud equatorem & tropicos, una cum ceteris omnibus que investigari poterunt per armillas astrolabium aut turketum. Cuius racio fundamentalis in hoc solo theoreumate consistit Euclidis :—

> Inter parallelas omnium equidancium linearum angulos relativos & magnitudines necesse est esse equales.

Capitulum primum de arte componendi tibiam primam.

Ad componendum igitur rectangulum separemus laminam unam eris quadrilateram orthogonam sed oblongam, longitudinis quatuor digitorum, latitudinis autem duorum, spissitudinis fere semis, que sit *abcd*; divisaque linea *ab* in 4 partes equales, sit una eius quarta *ae*; medietas quoque linee *ac* sit *af*; a quibus terminis *f* & *e* ducantur perpendiculares seu equidistantes super opposita latera que sint *fg* et *eh*, intersecantes se super punctum unum *i*. Item divisa linea *ae* in duo equalia ad punctum *k*, producatur equidistans a puncto *k* ipsi linee *ac* super lineam *cd* que sit *kl*, acceptaque linea *ok*, secundum quantitatem linee *ka*, & posito centro in puncto *o*, fiat circulus *ok*. Totumque superfluum quadrilateri *kf* preter semicirculum abradamus. Similiter & totum quadrilaterum *eg* abscindatur; factoque foramine triangulari & decenter orbiculato cum suis

marginibus in quadrilatero *fh*, cuius basis erit in linea equidistanti linee *ch* & cuspis versus lineam *fi* in linea *kl* apud *m*, depositoque superfluo apud angulum *f*, talis apparebit figura. Et tales tres laminas preparemus quarum prima sit robustior, secunda parum subtilior et tercia mediocris, quas tres tibias nominamus.



WORKING DRAWINGS FOR THE CONSTRUCTION OF THE RECTANGULUS, 1326.

C. C. C. MS. 144, *f.* 79. *See also pp.* 33, 34.

Capitulum 2 in artem componendi coxas.

Capiamus iterum laminam alteram prioris spissitudinis sed quadratam, cuius latera sint equalia linee *fc*, & sit quadratum istud *fcbd*. Divisaque linea *fc* per equalia ad punctum *g*, producatur equidistans linee *fb*, que sit *gh*, in cuius medio *o* posito centro fiat circulus equalis priori *ok*; ductaque contingente linea & equidistante linee *bd* super *cd*, que sit *li*, totum superfluum quadranguli *gi* abradamus preter semicirculum et apparebit talis figura quam coxam vocamus. Si igitur de circulo tibie abradamus medietatem spissitudinis eius in parte aversa ab aspectu, et de circulo coxe abstulerimus medietatem spissitudinis eius in parte opposita aspectui & applicemus coxam tibie in concavitatibus circulorum & transierit unus paxillus cum equo per centrum utriusque circuli sicut in opere astrolabii satis docetur, apparebit tibia cum sua coxa, quasi pars una, excepto quod coxa moveri possit super circulum tibie motu elevacionis & depressionis tantundem. Possumus autem opere liniari decenter coxam cum suis lateribus perlimare & compositorum talis apparebit figura. Deinde consimilem coxam aptabimus secunde tibie proporcionatam sibi in subtilitate si fuerit tibia secunda minor aut subtilior prima. Tercie vero tibie non coxam aptabimus sed hallidadam cum pinulis perforatis, coniungemusque hallidadam ipsi tibie cum paxillo & equo fortiter, ita quod motus eius elevacionis & depressionis sit difficilis sicut in astrolabio, sed multo difficilior & strictior sit motus duarum coxarum super suas tibias, itaque nullo levi pondere coxa super tibiam deprimatur. Eritque firmacio hallidade ad terciam tibiam seu supremam cum paxillo & equo, sicut dictum est de tibiis atque coxis & firmacio equorum ex parte aversa ab aspectu nostro erit, & erit hallidade cum tibia tercia talis figura. Nec erit aliqua concavitas in circulo huius tercie tibie sicut in ceteris. De longitudine autem hallidade suo loco dicemus.

Capitulum tercium in artem componendi columpnam seu basim instrumenti.

Preparabimus post hec columpnam unam decentem ligneam vel eream prout placet ad supportandum perpendiculariter instrumentum super planiciem orizontis, cum fuerit applicatum ad opus, que sit columpna *qp*, habens basim bone fixionis apud *p*. Et in epistilo apud *q* superemineat unus paxillus perforatus cum equo perpendiculariter & in directum medietatis columpne que est *qp*. Deinde fiat, in medio basis foraminis triangularis prime tibie, foramen aptum pro paxillo

firmato in supremitate columpne, ita quod cum prima tibie fuerit applicata ad columpnam & firmata cum equo possit tibia super columpnam moueri motu molaris, hoc est ab oriente per meridiem in occidentem, & in applicacione prime tibie cum columpna talis apparebit figura. Consimiliter fiet paxillus perpetue firmitatis super capud tam prime coxe quam secunde & foramina illis apta in secunda tibia & tercia, sicut de prima tibia est dictum ; que omnia cum fuerint invicem applicata, scilicet columpna, prima tibia, prima coxa, secunda tibia, secunda coxa, tercia tibia cum hallidada, & producta fuerit linea *pq* usque in summitatem tercie tibie ipsa transibit per centra omnium paxillorum & in parte opposita nostro aspectui tanquam una superficies apparebit, ut presens ostendit figura.

Capitulum quartum in composicione regularum ex ere[1] *tibiis applicandarum & de longitudine hallidade.*

Et cum preparate fuerint ipse tres tibie, concavabimus superfluum singularum quod est apud *di* ita quod singulis tibiis applicari possint regule eree decenter planate, quante voluerimus longitudinis, latitudinis vero *hi*, eritque firmatio earum fortis & ex parte aspectui nostro aversa, ita quod in parte opposita nostro aspectui ipsius regule & tibie appareat superficies quasi una cum fuerint conclavate ; oportetque hallidadam tante esse longitudinis quod perpendiculum ab eius fine descendens tangat fines omnium regularum. Deinde faciemus alias tres regulas ereas similes prioribus & equales in latitudine & spissitudine set habebunt longitudinem equalem totis tibiis cum suis regulis conclauatis ita quod cum mote fuerint[2] motu molaris super paxillum sicut & tibie ut est dictum perpendiculum hallidade earum fines contingat quemadmodum tibiarum ; propter quod nota quod oportet paxillos super quorum

Superficies istius regule debet diuidi secundum quod diuiditur inferius in isto folio.
Ista regula erit fixa & debet diuidi super latera & non in medio secundum quod diuiditur regula inferius in isto folio
regula diuisa ad equinoxialem & fixa

[1] ex latone in MS. Laud. [2] fuerit, MS.

centra tibie reuoluuntur tante esse altitudinis quod possint recipere[1] istas regulas & tibias ipsas simul circumvolventes super eas, sicut tibie ut est dictum, & cum coniuncta fuerit prima regula & prima tibia paxillo columpne[2] talem representabit figuram, & consimilem facient regule cetere & tibie coxis iuncte. Parum quidem differunt coxe ab epistilo columpne nisi quod hee mobiles hoc immobile perseverat. Hec de partibus rectanguli dicta sufficiant.

Capitulum quintum in diuisione & mensuracione omnium regularum.

Primam regulam prime tibie conclauatam, quam eciam ceteris omnibus esse expedit laciorem marginabimus tribus marginibus in parte opposita nostro aspectui quarum due margines erunt prope latera latitudinis & tercia in medio latitudinis eius erit. Marginem hic uocamus strictam superficiem inter duas lineas rectas equidistantes sed prope iacentes contentam; duoque maiora spacia inter tres margines has contenta diuidemus utraque in duo equalia per lineas prioribus equidistantes. Exibuntque iste linee marginarum (*sic*) a radice paxilli super quem tibia circumfertur. Habebimus itaque in superficie regule tres margines pro diuisionibus & quatuor alia spacia laciora pro litteris inscribendis, quorum duo spacia collateralia medie margini assignentur; cetera duo spacia suis marginibus in lateribus regule seruient ut patet in presenti figura. Ambas igitur margines exteriores a radice paxilli usque ad finem longitudinis earundem diuidemus in 60 partes equales diuisione fideli & uocabuntur hec sectiones gradus seu partes cordarum, quarum parcium quamlibet diuidamus in 60 minuta uel in quotlibet longitudo permittit. Spacia eciam superioris & inferioris marginis diuidamus per quinos gradus & quinos[3] pro litteris numerorum. Mediam autem marginem diuidemus per tabulam corde recte & uerse sicut circuli solent per tabulas diuidi & ambo spacia diuidantur per quinos gradus & quinos. In superiori quidem spacio scribantur littere numerorum graduum & signorum & in inferiori spacio similiter sed econtra. Post hec diuidemus omnes ceteras regulas per duas margines tantummodo laterales in 60 partes equales ut prius nec habebunt iste regule mediam marginem cum spaciis alternatis; propter quod omnes cetere regule esse poterunt stric-

[1] retinere, L. [2] conlumpne, MS.

[3] In the diagram, which seems to be in different ink and by another hand, the division is into six degrees not five. *See* p. 34.

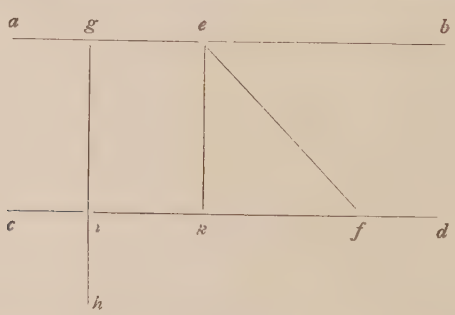
ciores quam illa que iam est descripta. Hallidada uero quia nullam diuisionem recipiet potest esse quantumlibet gracilis atque stricta. Postremo in fine cuiuslibet regule filum cum perpendiculo appendatur. Et nota quod superior corda que uocatur corda recta incipiet a paxillo uersus finem regule, et inferior corda que dicitur corda uersa a fine regule uersus paxillum scribetur. Similiter in inferiori spacio medie marginis scribentur gradus trium signorum a paxillo uersus finem; in inferiori spacio fiat econtra.

Explicit ars componendi rectangulum.

Incipit ars operandi cum illo.

Prefacium.

Rectangulus omnium circulorum magnorum in spera solos semidyametros continet; que eciam etsi ut in spera non ab eodem centro procedant nil refert, nec ex hoc potest instrumentum hoc in aliquo argui falsitatis. Instructis quidem in disciplinalibus mathematicis satis constat & est omni theoreumate certior proposicio hec subiecta. Si ab aliquo puncto alterius paralellarum super alteram perpendicularis ducatur equalis in longitudine alteri linee inter easdem paralellas ex obliquo contente, necesse est perpendicularem paralellas exire, partemque eius inter paralellas contentam esse cordam rectam arcus cuiuslibet anguli circa terminos oblique linee; residuum vero perpendicularis extra paralellas pretensum cordam esse uersam illius arcus; quo deficit arcus anguli acuti circa terminos oblique a quarta circuli est necesse. Ex-



This diagram is in MSS. Digby 168 and Laud 657, f. 48v, but not in C.C.C. No. 144.

empli gracia sint due paralelle *ab* & *cd*, inter quas obliqua contenta sit *ef*, perpendicularisque ducta a puncto unius para-

lellarum *g* sit *gh*, equalis linee oblique *ef*, punctusque ubi intersecat paralellam *cd* sit *i*. Dicimus ergo quod *gi* minor est linea *ef*; et quod linea *gi* est corda recta arcus anguli *aef*,[1] et similiter arcus anguli *feg*, et quod linea *ih* est corda uersa arcus anguli *fek*, quo angulo angulus *aef*[1] minor est recto. Hec ostendere instructis in sciencia corde & arcus, quibus solis dignum est hoc instrumento in consideracionibus suis uti, supervacuum iudicamus.

Capitulum primum huius partis de nominibus parcium rectanguli.

Omnes partes rectanguli certis uocabulis nuncupare.

Prima pars que facta est ad modum columpne basis rectanguli dici potest. Paxillus basis dicitur ille clauus supereminens in summitate basis perforatus pro repagulo qui equs uocatur ut in astrolabio continetur. Prima regula uocatur illa lamina gracilis & oblonga que circa paxillum basis molariter circumfertur. Prima tibia dicitur pars illa que habet regulam sibi confixam prime regule in longitudine coequalem, que similiter mouetur super paxillum basis motu molari. Prima coxa uocatur pars illa concauata in qua iunctura prime tibie sicut in cardine suo mouetur super paxillum motu eleuacionis & depressionis, cum equo firmato ut in astrolabio in parte a nostro aspectu auersa. Habetque hec coxa paxillum in summitate eius cum equo sicut epistilus basis[2] habet. Secunda regula & secunda tibia mouentur super primam coxam circa paxillum sicut dictum est de prima regula & prima tibia respectu paxilli basis. Secunda coxa per omnia similis est prime coxe in summitate secunde tibie situata. Tercia regula & tercia tibia sunt que super secundam coxam mouentur motu molaris. Nec habet tercia tibia supra summitatem eius coxam, ut cetere, sed loco coxe habet hallidadam. Hallidada est uirgula longa firmata in summitate tercie tibie, mota super paxillum motu eleuacionis & depressionis ut per foramina in eius tabellis altitudo syderum discernatur. Perpendiculum basis uocatur filum quod in superficie columpne appenditur cum modico pondere ad rectificandum situm tocius rectanguli. Cetera autem perpendicula atque corde a suis regulis nominantur. Paxillus uocatur clauus rotundus coniungens duas particulas instrumenti inuicem, ut altera parte quiescente altera moueatur. Equs uocatur repagulum confirmans laminas intra paxillum.

[1] *bef* in MSS. D & L.

[2] MS. L omits 'basis'.

Capitulum 2 de arte cognoscendi cordam rectam & uersam arcus dati.

Cordam rectam & uersam cuiuslibet arcus infra quartam circuli per arcum datum & quemlibet arcum per cordam datam cognoscere.

Quod si placuerit, appende perpendiculum secunde tibie super hastam prime tibie ad quemvis arcum datum, ita quod super arcum illum orthogonaliter cadat filum, & quod est de hasta tibie inter filum & paxillum est corda recta arcus computati a paxillo uersus finem haste; quod autem extra filum fuerit computando a fine haste ad filum est corda uersa arcus illius qui est similiter extra filum. Econtra facias si per cordam scire uolueris arcum suum. Et nota quod tunc demum cadit filum perpendiculariter super partes regule seu haste quando ipsum cadit super equales partes cordarum in utraque margine protractarum, & hec est causa precipua quare in singulis regulis corde arcuum duplicantur. Sinus autem rectus & uersus arcus maioris quarta circuli de facili ex premissis habetur. Nam omnis sinus rectus arcus minoris quarta circuli est sinus rectus arcus residui de semicirculo. Et omnis sinus uersus arcus maioris quarta circuli infra semicirculum maior est semidiametro per quantitatem corde recte illius arcus quo ille arcus datus est maior quarta circuli, sicut alibi est ostensum.

Capitulum 3 de arte inveniendi meridiem uille date.

In omni orizonte ueram meridiem inuenire.

Quod si placuerit, pone instrumentum super basim suam in aliquo loco eminenti, quo sol aut stella fixa toto die aut nocte possit per hallidadam intueri, erigaturque semper basis perpendiculariter super superficie orizontis. Deinde prime regule cuspidem apta ad meridiem prope uerum; qua ibidem immobiliter perseuerante moue primam tibiam cum toto residuo instrumenti in ortu uel prope ad solis aspectum, & eleua uel deprime hallidadam usque radius solaris transierit per utrumque foramen, si de die fueris operatus; uel usquequo stella oriens per ipsa foramina possit uideri, si de nocte fuerit opus tuum; quod cum apprehenderis, appende filum appensum in cuspide prime tibie perpendiculariter super gradus prime regule & scias cordam uersam & arcum eius nota. Item cum sol uel stella tetenderit ad occasum, prima regula semper immota, moue primam tibiam cum toto residuo quod est super ipsum ad solem uel stellam ut prius, hallidada existente in eadem disposicione in qua prius erat, quando per eius fora-

mina[1] transiit radius uisualis & obserua tempus & horam in qua demum poteris intueri eandem stellam uel solem per ipsa foramina tabellarum & tunc cognosce ut prius per filum appensum in cuspide prime tibie cordam uersam & arcum distantem a regula prius dicta; que si fuerit equalis corde prius accepte scias ipsam regulam veraciter in meridie esse sitam. Quod si fuerint diverse, coniunge utrosque arcus &, prima tibia nusquam mota, per accessum uel recessum regule a prima tibia usque quo filum prime tibie cadere possit perpendiculariter super cordam uersam medietatis iam compositi arcus ex utrisque; quo facto scias cuspidem regule prime ueraciter ad meridiem quesitam extendi. Hoc genus querendi lineam meridionalem per solem, optimum est quando sol est prope tropicos.

Capitulum 4 de altitudine stelle super orizontem & Azimuth.

Azimuth & altitudinem stelle apparentis super orizontem apprehendere.

Quod si placuerit, pone primam regulam directe ad meridiem iam inuentam, deinde totum residuum instrumenti moue motu prime tibie ad stellam & tunc eleua uel deprime hallidadam usquequo radius stelle transeat per utrumque foramen; quo facto, extende filum prime tibie ortogonaliter super primam regulam & quicquid fuerit de regula intra filum uersus paxillum ipsum est corda recta distancie stelle a puncto ueri orientis, si fuerit stella in illa plaga que est inter meridiem & orientem; et quod de regula fuerit extra filum est corda uersa distancie stelle a uera meridie. Similiter intellige de azimuth occidentali, si fuerit stella in tali plaga & sic deinceps. Item filum hallidade ubicumque ceciderit perpendiculariter super primam tibiam, quod fuerit intra filum, est corda recta distancie stelle a cenith; quod uero de regula fuerit extra filum est corda uersa eleuacionis stelle a circulo orizontis, sed habitis cordis per secundam huius de facili patent arcus. Et nota quod azimuth proprie est longitudo stelle a meridie; altitudo autem est proprie latitudo stelle ab orizonte.

Capitulum quintum de latitudine ville tue.

Latitudinem regionis per stellam non occidentem deprehendere.

Quod si placuerit conuerte primam regulam & totum eciam instrumentum fideliter ad septentrionem. Deinde cum fuerit aliqua stella perpetue apparicionis in directo instrumenti, hoc

[1] foramen, D & L.

est in linea septentrionali, apprehende cum allidada eius eleuacionem ab orizonte & nota cordam eius rectam & uersam secundum doctrinam premissam, & cum iterum peruenerit stella illa ad lineam septentrionalem, iterum nota eius altitudinis cordam uersam aut rectam. Oportet namque bis ipsam stellam transire per septentrionem, semel in maxima eius elevacione & semel in maxima eius depressione. Deinde illarum duarum cordarum uersarum arcus quere & medietatem excessus maioris arcus super minorem arcui minori adde & arcus coniunctus erit latitudo regionis quesita, & eius corda uersa erit corda latitudinis. Est quidem latitudo regionis distancia cenith capitis a maxima eleuacione capitis arietis, cui equalis est altitudo poli septentrionalis. Si autem operatus fueris per cordas rectas, ut predictum est de cordis uersis, arcus coniunctus erit eleuacio capitis arietis seu distancia poli septentrionalis a cenith capitis uille tue.

Capitulum 6 de longitudine & latitudine stelle respectu circuli equinoxialis.

Latitudinem stelle a circulo equinoxiali una cum longitudine eiusdem a puncto equinoxialis existentis in medio celi deprehendere.

Quod si uolueris, conuerte primam regulam ad meridiem tibi notam ; deinde eleua sub eadem linea meridionali secundam tibiam per motum prime coxe usquequo filum secunde tibie cadat perpendiculariter super primam tibiam in gradum & minutum corde uerse altitudinis capitis arietis per premissa. Quo facto, stabilietur in illo situ sub meridie, secunda tibia[1] fixa semper. Deinde moue terciam tibiam ad aspectum stelle cum hallidada & eleua uel deprime hallidadam usquequo deprehenderis radium huius stelle. Quod cum perfeceris extende filum tercie tibie super terciam regulam existentem adhuc sub linea meridionali &, ut supra, quod fuerit de regula extra filum ipsum est corda uersa longitudinis stelle a puncto equinoxiali existenti in meridie. Quod autem de regula fuerit intra filum ipsum est corda recta residui de quarta circuli existentis inter ortum & meridiem uel inter occasum & meridiem. Item uide super quot partes & minuta signata in tercia tibia cadit filum allidade, & quod fuerit extra filum est corda uersa latitudinis stelle a circulo equinoxiali, bona fide. Et quod de tibia est intra filum, ipsum est distancia stelle a polo mundi. Et nota quod si cuspis hallidade deprimatur sub tercia regula erit latitudo meridionalis. Si uero eleuetur supra erit latitudo stelle septentrionalis.

[1] secundam tibiam, MS.

Capitulum 7 de declinacione stelle & latitudine ab ecliptica.

Declinacionem gradus ecliptice existentis in medio celi a circulo equinoxiali per solis aspectum deprehendere.

Quod si placuerit, dispone instrumentum sub linea meridiana, sic quod eleuetur secunda tibia secundum quod exigit altitudo capitis arietis in meridie per antepremissam scilicet quintam huius. Deinde conuerte terciam tibiam cum allidada ad solem & tunc eleua terciam tibiam uel deprime usquequo radius solaris transeat per foramina pinnularum; sitque semper allidada equidistans tercie tibie. Quo facto, absque motu elevacionis vel depressionis tercie tibie, moue ipsam terciam tibiam sub linea meridiana & extende filum tercie tibie super secundam tibiam perpendiculariter & quod fuerit de secunda tibia extra filum ipsum est corda uersa declinationis puncti ecliptice existentis in meridie a circulo equinoxiali. Vide ergo cui gradui ecliptice debetur talis declinacio, & ipse est gradus medii celi uere.

Capitulum 8 de vero gradu solis per eius aspectum habendo.

Certum locum solis per solum eius aspectum apprehendere.

Quod si uolueris, per premissam inuenies gradum medii celi & terciam regulam dispones sub meridie secundum quantitatem declinacionis eiusdem gradus ab equatore diei, quo facto ipsa tercia regula et, toto quod sub ea continetur in instrumento immobiliter existente in suo situ secundum premissarum doctrinam, moue terciam tibiam ad aspectum solis. Quod si bene feceris, statim sine aliqua elevacione vel depressione hallidade a tercia tibia radius ipse solaris transibit per utrumque foramen. Tunc extende filum tercie tibie super regulam terciam orthogonaliter & quod fuerit extra filum de tercia regula erit corda uersa arcus elongacionis ueri loci uel gradus solis a gradu & puncto medii celi de ecliptica & ipse punctus iam est notus. Erit ergo notus uerus locus solis per predictam huius.

Capitulum 9 de uero loco lune cognoscende in longitudine & latitudine.

Verum locum lune una cum latitudine eius ab ecliptica cognoscere.

Quod si placuerit, in hora qua simul uideri possunt sol & luna super orizontem secundum premissam & antepremissam dispone terciam regulam sub meridie secundum declinationem gradus medii celi in hora consideracionis tue & scias memori-

ter tunc uerum locum solis. Deinde moue terciam tibiam ad aspectum lune una cum hallidada equidistante; quod si eius radii transeant per foramina pinnularum scias quod luna nullam habet latitudinem ab ecliptica. Sin autem, eleua uel deprime allidadam usquequo eius radius transeat per utrumque foramen. Quo facto, si extenderis filum allidade orthogonaliter super terciam tibiam, quod de tibia fuerit extra filum erit corda uersa latitudinis lune ab ecliptica, & si allidada fuerit supra terciam tibiam erit latitudo septentrionalis. Si uero cuspis eius sit sub tercia tibia, latitudo [erit] meridionalis. Item extende filum tercie tibie super terciam regulam orthogonaliter & quod fuerit de tercia regula extra filum est corda uersa arcus distancie ueri loci lune a gradu medii celi, & ipse est notus & per consequens notus est uerus locus lune, & sic deprihendes uera loca omnium planetarum.

Capitulum 10 de ueris locis stellarum fixarum & planetarum in longitudine & latitudine.

Distanciam cuiuslibet stelle fixe tam in longitudine quam in latitudine a quolibet puncto in ecliptica designato uno cum latitudine & gradu cum quo peruenerit ad meridiem demonstrare.

Quod si uolueris, de longitudine & latitudine eius respectu ecliptice omnino fac sicut dictum est de luna & ceteris planetis erraticis. De gradu uero medii celi & de latitudine ab equinoxiali sic facies. Disposita secunda tibia sub meridie secundum altitudinem capitis arietis, sicut dictum est capitulo 6 supra, conuerte terciam tibiam cum allidada ad lunam, ita quod radius lune per ipsa foramina transeat, & tunc inter allidadam & terciam tibiam sit distancia quam exigit latitudo lune, si luna latitudinem habeat; deinde terciam regulam equidistantem tercie tibie moue sub meridiem. Cum igitur peruenerit stella ad meridiem per uerum locum lune deprehendes semper gradum medii celi & per consequens gradum cum quo stella peruenerit ad meridiem. Omnia hec aliter cognosci poterunt sicut docet ars armillarum & turkety; cetera eciam omnia que per astrolabium sciri possunt. Uerum quia propter hec que explicita sunt factum erat instrumentum rectanguli & inuentum, quia eciam per ea que iam dicta sunt sufficienter docili discipulo patet uia ad omnia ea que per cetera instrumenta sciri possunt, ponimus istic finem.

B. THE ALBION

By Richard of Wallingford, 1326–7

Transcribed by the Rev. H. Salter from MS. C.C.C. No. 144 and now printed for the first time and collated with MS. Laud misc. 657, f. 10v.

See p. 31.

Incipit secunda pars.

Albyon ad instar planisperii tocius spere celistis concentricos, ecentricos, & eciam epiciclos pro uariis stellarum motibus machinatos errancium seu fixarum mira continet breuitate. Cuius composicio admodum facilis est eciam rudibus, prehabita tamen proporcionalium noticia circulorum ad tam dispares circuitus planetarum. Huius igitur gracia opere precium fuerat premonstrare qualiter huiusmodi circuli in apta materia poterunt inueniri, & deinde subdere consequenter quo artificio idem circuli diuidi debeant & inscribi; quia in horum diuisione proporcionalium circulorum uerifica & subtili plurimum consistit huius bonitas instrumenti.

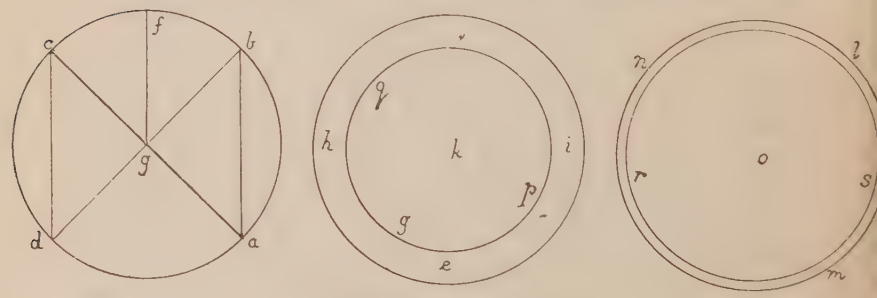
Capitulum primum de arte componendi materiam tocius instrumenti.

Aptare materiam operi est accipere unam laminam auricalci pollitam & planam & in ea describere circulum super g. centrum cuius diametrum 12[1] ad minus contineat pollices & eidem circulo maximum quadratum inscribere quod sit a. b. c. d. & super summitatem linee g. f., semidiametri orthogonaliter secantis costam c. b., aliquid superfluum extra circulum designare pro armilla suspensoria instrumenti. Et duas superfluitates in summitatibus duarum costarum d c et a b pro pinulis aspectuum[2] retinendis & deinde cum circino peracuto quicquid de lamina a b c d extra circumferenciam superfluit resecare preter has tres superfluitates que sunt apud f. & c. & b. Deinde huic lamine sic formate inquirantur alie due lamine per omnia similes & equales & fiat una earum e h i & eius centrum k, altera uero sit l m n & eius centrum o; et super laminam e h i fiat circulus equalis maximo circulo inscriptibili quadrato a b c d & sit iste circulus p g q

[1] 16 vel 12, L.

[2] aspicientium, L.

supra quam circumferenciam cum circino peracuto diuidamus laminam ipsam h g i[1] in duas partes equales cuius pars exterior erit armilla h i & similiter lamina circularis p g q. Eodem modo de tercia lamina l m o n abradamus subtiliter cum circino peracuto unam armillam cuius latitudo sit subtripla ad latitudinem armille h i[2] & sit hec armilla l m & n & residuum interius circulare sit lamina r o s; post hec conclauentur iste due armille h i[2] et armilla l m n altrinsecus limbo lamine prime a b & cum solidatura competenti firmissime conglutinentur. Et tunc aptari faciamus duas residuas laminas



FIGURES 2-4 ON F. 54v.

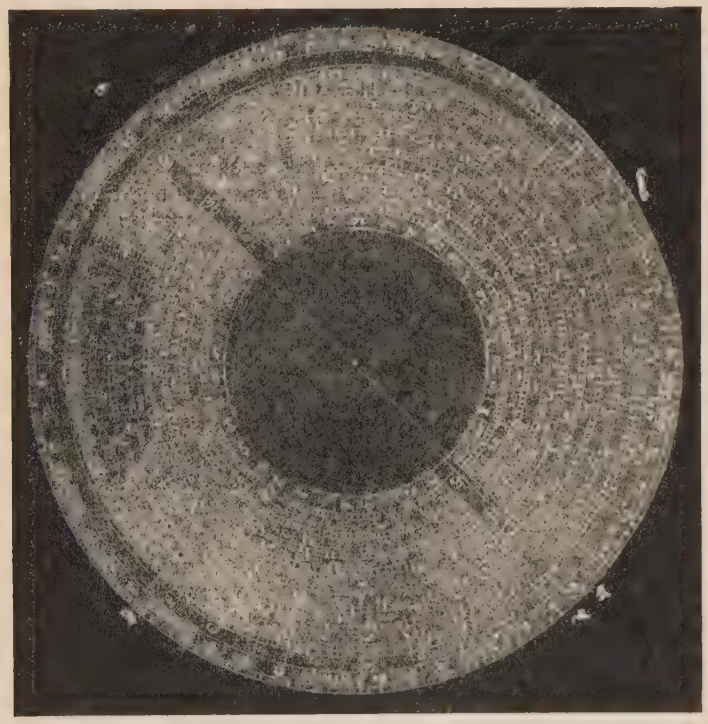
p g q & r o s ut recipi possint inter concauitates limborum aptissime ita quod massa trium laminarum coherencium appareat tanquam corpus unius superficiei ex utraque parte planissimum. Posset autem lamina media a b c d cum suis limbis altrinsecis opere tornatili de eadem massa componi & due lamine breuiores p g q & r o s cum concauitatibus replendis aptari. Quibus meliori modo compositis in duabus superfluitatibus c & b erigantur due pinule perforate equidistantes linee g f ex parte limbi l m o n & superfluitate f imponatur armilla suspensoria, & completum est.

Capitulum 2 de modo inscribendi circulos limbi primi.

Et cum preparata fuerit materia instrumenti consolidemus utramque laminam p g q & r o s in locis suis, ita quod ante completam instrumenti facturam nullatenus moueantur e loco. Et incipientes a diuisione limbi maioris protrahamus occulte diametrum a g c & partem diametri que cadit in limbo h i diuidamus in 10 partes equales & faciamus per quamlibet diuisionem transire circulum unum super g centrum descrip-

[1] e h i, L. [2] e h i, L.

tum. Et habeat quodlibet spacium inter duos circulos extra se unam breuem marginem pro diuisionibus graduum capiendis excepto secundo spacio quod habebit marginem intra se. Erunt itaque 10 spacia pro litteris numerorum & totidem margines pro gradibus circulorum. Deinde tercium marginem numerando ab extra diuidamus fideliter in 360 partes equales & spacium eius sequens per senas et senas partes equales pro litteris graduum inscribendis, & discribamus gradus marginis



in 12 signa, & in spacio primorum 6 graduum cuiusuis signi intituletur nomen signi illius, uel in spacio ultimorum 6 graduum distincte sculpetur quotum fuerit illud signum; in residuis autem spaciis 6 graduum eorum numeri insculpentur, & incipiat numerus signorum ex opposito c ad punctum a; hoc nota. Post hoc diuidamus extimum spacium cum suo margine tali arte; a puncto eius in margine quod est in directo a separabimus contra naturalem successionem signo-

rum unum arcum 5 graduum 10 m*inutarum* 27 s*ecundarum* quam precise fierit poterit, qui sit in extimo margine arcus a x, & totam residui[1] marginis s[cilicet] arcum a c x diuidamus in 360 partes equales, et si fideliter sit diuisum arcus x a de eiusdem partibus continebit 5 partes et quartam unius. Post hec incipientes a puncto a distribuamus easdem diuisiones per menses dando cuilibet mensi tot diuisiones quod habuerit ipse dies; ponentesque principium mensis Marcii apud a, diuidamus spacium eiusdem marginis per 6 & 6 partes inscribendo nomen mensis in primo spacio 6 dierum mensis eiusdem, & habebit ultimus mensis superfluum unius quarte diei. Medium spacium cum margine nondum diuiso diuidemus hoc modo; semicirculum eius b a d diuidemus in 90 partes equales & spacium marginis proximi in 18 & inscribantur numeri[2] graduum incipientes apud d uersus a. Reliquam uero medietatem marginis[3] in 12 partes equales secemus quas 12 horas in spacio margini proximo[4] titulabis; quamlibet illarum 12 parcium in 60 partes diuidemus si latitudo marginis hoc permittit et erunt minuta horarum. Incipietque earum computacio a puncto d uersus c, uocabiturque circulus primus anni[5] solis & semicirculus b c d circuli secundi uocabitur arcus horarum & alter semicirculus d a b uocabitur altitudinis[6]; tercius autem circulus est vice zodiaci spere octave, & completum est. Verumptamen antequam fiunt 7 interiores circuli cum suis marginibus super diametrum limbi apud a & apud c producantur due linee altrinsecus equidistantes diametro pro margine divisionum & spacio litterarum inscribendo, sicut interius dicetur capitulo 4, sicut in presenti patet in figura.

Capitulum tercium de divisione orbis Saturni.

Quartus circulus cum suo margine uocabitur orbis Saturni, cuius marginis diuisio fiat ita. In vacuo spacio lamine p g q semidiametrum g a per quartum & septimum prime huius inueniantur centra equantis & deferentis Saturni cum proporcione semidiametri eorundem ad id quod cadit int[us] centrum deferentis & g centrum terre. Quibus compertis protrahantur occulte & delebiliter deferens atque equans & diuidatur equans in 360 partes equales occulte, incipiendo in directo a puncti ⟨ubi ponitur⟩[7] a u x equantis, & regula exiens

[1] residuum, MS. [2] numerum, MS.

[3] A note in a later hand 'Marginem vocat id quod est inter duos circulos propinquiores, inter quos est divisio graduum. Spacium vocat id quod est inter duos circulos distanciores inter quos intitulantur numeri graduum & horarum seu signorum.'

[4] proximum, MS; proximi, L.

[5] circulus anni, L. [6] altitadinis, MS. [7] L.

a centro equantis per diuisiones has singulas signet easdem in circulo deferentis. Et iterum alia regula fixa in centro terre g transiens super omnes diuisiones iam in deferente signatas transferat omnes ad marginem orbis Saturni. Post hec ille 360 partes in orbe Saturni signate distribuantur per 12 signa incipiendo in directo a, & spacium margini adiunctum per 6 & 6 partes diuidatur omnino sicut dictum est in divisione zodiaci octaue spere, & in ultimo spacio 6 graduum signi sculpentur distincte quorum fuerit illud signum. Isto modo autem omnino diuidemus septimum[1] circulum cum suo margine qui erit vice orbis Iouis & sextum circulum qui erit orbis uice Martis; nullam tamen harum diuisionum signemus infra spacium transuersum apud a & apud c sed omnino intacte permaneant usque ad capitulum 4 ubi docebitur quomodo diuidentur; & completum est.

Capitulum 4 de modo communi operandi in diuisione orbis.

Ad maiorem huius operis declarationem sit circulus orbis Saturni a b c d super centrum g. Et quia quarta et septima conclusio primi huius sunt generales ad inueniendum centrum equantis & deferentis in quouis puncto linee exeuntis a centro g terre, & circulos proporcionales quantumlibet magnos uel breues per quantumque[2] distanciam centri epi[cic]li ab auge deferentis suppositam & per notam eiusdem distancie equacionem que uocatur equacio centri uelimus[3] deinceps uti distancia centri ab auge a 3um signorum qui sit arcus a b & separemus a puncto b uersus a arcum equacionis talis centri qui sit arcus b f. Nam per calculum Ptolomei in radicibus Almagesti fiunt equaciones centri ad tercia signa sic. Saturni equacio centri trium signorum 6 gra' 31 min', Iouis 5 gra' & 15 min', Martis 11 gra' & 23 min', solis et Veneris 1 gra' 59 min', Mercurii vero 3 gra' & 1 min.; sit igitur arcus b f 6 gra' & 31 min' & producta linea g f in eadem signemus punctum h vice centri epicicli caueaturque in operando ne linea g h sit maior uel equalis linee g b; nam si ita fuerit non cadent isti ecentrici infra spacium p g q. Deinde a puncto h producatur equidistans linee g b super lineam g a ad punctum i. Patet ergo per quartam primi quod i est centrum proporcionale equantis. Posito ergo centro in medio inter g & i circumducatur circulus per h punctum cui fiat equalis super centrum i, quia equans & differens ymaginantur a disciplinatis esse equales. Deinde diuidatur circulus equans qui est super centrum i in 360 partes equales. Et tum fixa regula in

[1] quintum, L. [2] quantamlibet, L. [3] nihilominus, L.

puncto i transeunte per singulos illos gradus, transferantur singule divisiones ille ad alterum circulum prius factum scilicet ad deferentem. Post hec regula fixa in g centro terre circumvolvatur regula super illas 360 divisiones in deferentem translatas, & signentur eedem diuisiones in circulo a b c d ad contactum regule cum circumferencia a b c d que est in loco orbis Saturni, & sic patet eius artificialis diuisio. [Fig. 6

Capitulum 5 de solis orbe.

Post diuisionem orbis Saturni & Iouis & Martis restat diuidere orbem solis. Inuento ergo ecentrico deferente solis per quart[am] primi huius & ipso diuiso in 360 partes equales, statim posita regula in centro g reuoluatur ipsa super singulas has divisiones & transferat eas ut prius ad marginem orbis solis. De quibus gradibus fiant 12 signa & intitulentur in spacio margini annexo omnino sicut predictum est de ceteris orbibus, & completum est.

Capitulum 6 de diuisione orbis Mercurii. [Fig. 7

Nunc superest dividere orbem Mercurii, quia orbis solis & Veneris sunt unius differencie in movendo. Per quartam pri[me] huius inveniatur ut prius centrum equantis Mercurii in semidiametro g a per centrum trium signorum & per equacionem eiusdem centri. Et per oc[tavam] pri[me] huius inueniatur quantitas semidiametri deferentis in debita proporcione ad distanciam centri equantis a centro terre ut uerbi gracia sit circulus orbis Mercurii a b c d super centrum g & centrum equantis f & circulus equantis a g secundum mensuram semidiametri f k. Item circulus brevis transiens per centrum equantis & centrum deferentis cuius semidiameter est equalis linee f g sit l f m. Deinde dividatur equans in 360 partes equales & circulus brevis in totidem vel in quot eorum fuerit possibile. Item a centro equantis producantur linee occulte indifinite per singulas divisiones equantis quorum 30 que sunt altrinsecus iuxta augem equantis a excedant semidiametrum equantis. Deinde circino quo fiebat circulus equans non mutato ponatur unus eius pes in circumferencia parvi circuli in prima divisione & signet unam divisionem in prima linea que exit a centro g per augem equantis ad punctum n. Item posito pede circini in secunda divisione parvi circuli computando contra naturalem successionem signorum extendatur alter pes circini non variati ad secundam lineam exeuntem a centro equantis f. computando lineas ab auge eius secundum successionem signorum, signando divisionem ad punctum o & sic deinceps currat alter

pes circini in parvo circulo tricesies sexagesies centro mutato quousque alter pes signaverit divisionem unam in singulis lineis a centro equantis eductis. Deinde fixa regula in centro g, volvatur super singulas has divisiones & transferat eas ad marginem orbis Mercurii a b c d, sicut pretactum est de ceteris, & distribuantur divisiones per 12 signa & gradus in spacio margini coherenti, & intitulentur ut cetere & examinetur opus uel si libet perficiatur per tabulam centri equati Mercurii & redit in idem. Et nota quod si equans & circulus ille parvus non possent commode signari in spacio lamine p g q fixo instrumento in aliqua plana superficie invenire poterimus centrum equantis extra superficiem limbi & quantitatem semidiametri deferentis & circulum illum brevem in quantalibet longitudine & magnitudine nec omnino variabit divisiones recipiendas in margine orbis Mercurii, & causa patet eo quod conclusio septima pri[me] huius generalis est & causa tangitur p[aragr]affo finali; & completum est.

Capitulum 7 de orbe lune.

Adhuc restat nonus circulus dividendus qui erit circulus orbis lune, cuius divisio fiet ita. Per sextam pri[me] huius inueniamus ecentricum deferentis lunaris & posita regula in centro g terre circumducatur regula super singulas divisiones marginis zodiaci spere octave & transferantur eedem divisiones ad deferentem lunarem. Deinde regula fixa in puncto opposite centro deferentis in diametro a c transferantur omnes divisiones deferentis ad marginem orbis lunaris & tunc spacium eius omnino intituletur sicut spacia orbium aliorum. Potest eciam hoc fieri uel examinari per tabulam centri equati lune & redibit opus in idem & completa est divisio primi limbi. Ultimo dividatur circulus decimus qui dicitur circulus uerus lune omnino sicut dividitur circulus orbis solis per maximam equacionem argumenti ad tria signa que est 5 gra' & 2 min' & distribuantur divisiones in signa & gradus ut pretactum est; & completum est.

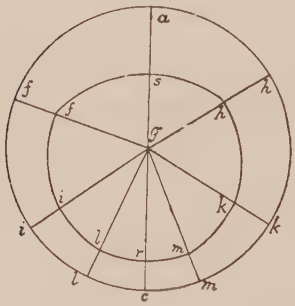
Capitulum 8 de ecentricis epiciclorum.

Post divisionem orbium planetarum in spacio limbi primi h i restat describere deferentes planetarum circa centrum epiciclorum suorum in spacio lamine p g q & inscribantur sensibiliter per doctrinam undecime pri[me] huius, & eorum centra accipiantur in semidiametro g c eruntque auges earum in directo pinnule c; et capi potest eorum mensura a gradibus marginis circuli altitudinis indifferenter uel a gradibus mar-

ginis zodiaci orbis octavi, sed tunc oportet duplare equacionem quia respectu centri c quilibet gradus est duplus in comparacione ad centrum g, sicut patet per nonam conclusionem pri[me] huius. Regula autem per quam capientur huiusmodi arcus fixa erit in c puncto in circulo medio communi duabus marginibus circuli altitudinis & zodiaci, & erit ordo istorum ecentricorum primo Veneris, secundo Martis, tercio Mercurii, quarto Iouis, quinto Lune, ultimo Saturni & intitulentur quorum sint ecentrici & completum est.

Capitulum 9 de ecentrico Mercurii. [Fig. 8

Ecentricum epicicli Mercurii oportet alio modo depingere quia non habet augem deferentis fixam & quia prius est planeta in maxima elongacione eius apparenti a centro epicicli quam fuerit centrum epicicli in augis opposito deferentis; & ideo ad remouendum difficultatem inveniendi locum stelle in ecentrico epicicli proporcionem motus centri epicicli in suo ecentrico deferente, et ad abreviandum multitudinem circulorum, maxime autem ut hoc instrumentum in nullo videatur a tabulis discrepare, fiat ecentricus epicicli Mercurii isto modo. In spacio lamine p g q posita regula in centro g separemus alterutra parte a duos arcus 64 graduum qui sunt arcus a f & a h protractis occulte lineis g f & g h. Item separabimus altrinsecus 2 arcus 4 signorum qui sunt a i & a k productis lineis occultis g i & g k; & iterum tercio separemus 2 arcus, utrumque 5 signorum & sint a l & a m, protractis lineis g l & g m. Deinde per decimam pri[me] huius inueniatur epiciclus occultus proporcionatus equacioni maxime viginti trium graduum & 53 minutarum & ubi iste circulus abscindet duas lineas g i & g k ponantur note i & k; secundo per eandem decimam pri[me][1] inueniatur epiciclus proporcionatus maxime equacioni viginti trium graduum & triginta duorum minutorum, & ubi iste epiciclus occultus abscinderet duas lineas g l & g m ponantur due note l m. Tercio inueniatur epiciclus proporcionalis equacioni viginti trium graduum & quindecim minutorum & abscicione linee g c ponatur nota r. Quarto inueniatur epiciclus proporcionalis equacioni maxime viginti unius graduum & quadraginta qua-



[1] huius, L.

tuor minutorum & ubi abscindit duas lineas g f and g h ponantur note f h. Quinto inueniatur epiciclus proporcionalis equacioni maxime 19 graduum et unius minuti & ubi abscindit lineam g a ponatur nota s. Deinde posito centro in linea g c a inueniatur arcus circuli qui transeat per tria puncta l r m & fiat arcus l r m tantum satis patens. Item posito centro in eadem linea c g a describatur arcus manifestus transiens per tria puncta f s h. Item posito centro in linea g k fiat arcus patens transiens per tria puncta f i l. Quarto posito centro in linea g i,[1] fiat arcus patens super tria puncta h k m, & complebitur circumferencia r l i f s h k m r fractus in quatuor punctis f h l m, habens staciones ad quatuor puncta s c i k,[2] in quo innuitur causa quare necesse est eam fieri super quatuor centra & super tres diametros; & iste circulus ecentricus non habet errorem sensibilem in instrumento cuius diameter est 60 cubitorum, & est abbreuians multos circulos ab instrumento in quo est ecentricus epicicli Mercurii circulus vere unus sicut contingit in ceteris 5 planetis; & fiant isti 6 ecentrici patentes valde & completum est.

Capitulum 10 de inscripcione circulorum continencium circulum anni solaris & jomyn. [Fig. 9

Perfectis sex ecentricis planetarum incipiamus novam operacionem in lamina p g q ac si nichil adhuc inibi sculperetur & primo separemus unum spacium cum margine & perficiamus circulum anni solis omnino sicut dictum est de primo limbo, capitulo secundo. Deinde separemus duo spacia competent[ia] pro litteris numerorum & marginem interceptum pro gradibus protrahendis, quem marginem diuidamus in 360 partes equales et compleamus orbem signorum, ut sepe dictum est, scribentes in exteriori spacio numerum signorum & graduum sicut exigit signorum successio naturalis. In interiori uero spacio scribantur idem numeri signorum & graduum sed contra successionem signorum, & erit incepcio huius orbis in directo[3] a. Deinde separemus a b d spacium cum margine & marginem eius diuidemus per unam tabulam adhuc[4] factam que intitulatur tabula motus jomyn equanti, cuius composicio patebit infra partem terciam[5] huius, ubi traditur ars componendi tabulam quibus alio modo operandi possent dividi circuli antedicti & distribuantur illi gradus in 12 signa & intituletur spacium marginis consimiliter ceteris & completum est.

[1] g r, L. [2] s r i k, L. [3] puncto, L. [4] ad hoc, L. [5] quartam, L.

Capitulum 11 de inscripcione circuli medii motus Saturni. [Fig. 10

Post circulum equacionis jomyn immediate separabimus unam brevem marginem cum duobus spaciis pro litteris numerorum, eritque circulus iste medius motus Saturni, cuius marginem taliter diuidemus. In directo a puncti separabimus de margine contra successionem signorum arcum a x secundum quantitatem 6 graduum marginis & 29 minutorum & 19 secundorum, quam precise estimari poterit a subtili. Deinde totum residuum arcum marginis ab a in x secundum successionem signorum diuidamus in 12 partes equales, que divisiones transeant per ambo spacia margini coadiuncta & quamlibet partem duodecimam in margine dividamus in 60 minuta, de quibus partibus continebit arcus residuus x a 13 minuta & 12 secunda si fideliter fuerimus operati. Et continue quinta vel sexta divisio marginis transeat per spacium margini proximi, in spacio sex vel quinque minutorum scribi poterit numerus eorum & 12 partes in spacio secundo intitulentur gradus 12, ut patet in presenti figura; verumptamen summo opere caueatur quod ita discrete fiant isti margines cum spaciis suis adiunctis quod non confundant circulos sex ecentricos prius factos, & completum est.

Capitulum 12 de circulo anni Iouis.

Circulum anni Iouis restat diuidere isto modo. Faciamus ut prius super centrum g immediate post circulum anni Saturni brevem marginem cum 2 spaciis & a principio marginis separemus contra signa arcum quatuor graduum 8 minutorum & 51 secundorum, quam precise poterimus, & sit arcus a x. Deinde totum arcum marginis residuum ab a in x dividamus in 30 partes equales & transeat quelibet divisio per ambo spacia marginis. Post hoc quamlibet illarum 30 parcium dividamus in 60 minuta & istarum divisionum sexta & sexta transeat per spacium margini proximum & in primo spacio margini proximo scribantur littere numeri minutorum; in secundo vero spacio scribantur littere numeri graduum. Si autem bene diviseris arcum magnum a x, continebit arcus residuus x a 20 partes & 58 secunda, hoc est 21 minuta fere; & completum est.

Capitulum 13 pro Marte.

Deinde perficiemus circulum anni Martis hoc modo. Super g centrum faciamus marginem cum unico spacio vel duobus & a principio marginis contra signa separabimus arcum a x,

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ut prius, 21 graduum[1] & 27 minutorum & 2 secundorum, & arcum residuum dividemus secundum successionum signorum in 6 partes equales, que divisiones transeant per spacium & per marginem; erunt quidem ille partes sex signa. Post hec dividamus quamlibet illarum sex partium in 30 gradus & de illis partibus graduum continebit arcus residuus x a undecim gradus & 24 minuta fere; quia ultra hoc continebit 18 secunda; & cum diviserimus similiter arcum x a intitulabimus spacium cum numeris signorum & graduum satis distincte, & completum est.

Capitulum 14 pro circulo anni Veneris.

Adhuc dividamus circulum anni Veneris isto modo. Separabimus ut prius unum vel duo spacia cum stricto margine super communem centrum g & a principio marginis resecemus[2] arcum a x contra signa, qui sit 17 min. & 52 sec. fere. Deinde totum arcum residuum marginis dividamus in 15 partes equales & quamlibet illarum parcium iterum in 15 dividamus. Deinde de hiis partibus faciamus signa, dantes cuilibet signo 30 partes & erunt septem signa & 15 gradus, & cum fuerit quilibet illorum graduum diuisus[3] in 60 minuta, uel quot fuerit possibile, de illis fractionibus continebit residuus arcus x a undecim minuta & 9 secunda. Deinde intituletur spacium litteris numerorum signorum & graduum sicut prius; & completum est.

Capitulum 15 de divisione circuli genzahar.

Superest circulum anni capitis draconis lune dividere. Consequenter separemus duo spacia cum margine & accipiamus a capite marginis arcum a x, contra signa, 6 graduum, 37 minutorum & 56 secundorum, & residuum dividamus in 19 partes equales que erunt gradus & quemlibet gradum dividemus in 60 minuta, & intitulabimus spacia, gradibus & minutis ut prius; & arcus residuus x a de illis partibus continebit 21 minuta & 22 secunda. Et si videatur divisio arcus a x in 19 partes equales aliqualiter tediosa, faciamus arcum a x, contra signa, 25 graduum, 14 minutorum, 31 secundorum quam precise poterimus & residuum secundum successionem signorum dividamus in 18 partes equales, & tunc continebit arcus x a de illis partibus 1 gradum & 21 minuta & 22 secunda, & redibit utraque operacio in id ipsum. Hec autem operacio presupponit certum motum medium omnium predictorum in una hora.

[1] gradus, MS. [2] resesemus, MS. [3] diuisum, MS. and L.

Capitulum 16 de circulo coniunctionis. [Fig. 11

His succedat circulus coniunctionis & preuencionis equate solis & lune, pro quo separabimus circulum habentem marginem & spacium unum pro litteris numerorum & a principio marginis seperabimus arcum a x, contra signa, 2 graduum & 30 minutorum & residuum dividemus in undecim partes equales & erunt 11 gradus. Quantitas autem unius illarum undecim parcium erit 32 partes & 30 minuta de gradibus zodiaci limbi eius, & quemlibet gradum dividemus in 60 minuta. Quo facto dividemus spacium marginis per 10 & 10 minuta & in illis spaciis scribentur littere numerorum pro minutis, preterquam in spacio ultimorum 10 ubi scribentur distincte numerus graduum. Post hoc, quam remoti poterimus commode, prope centrum g ut puta inter ecentricum Saturni & Iovis, separabimus circulum unum habentem marginem & spacium & a capite marginis contra signa resecemus arcum a x ut prius, cuius quantitas sit 9 gradus 35 minuta[1] & 34 secunda & residuum secundum successionem signorum dividemus in 12 partes equales; & si pars terciadecima extenderit se ultra a usque 19 gradus 31 min. & 45 sec. fideliter est divisum. Et erunt hee partes 12 lunaciones, quarum quamlibet dividamus in 4 partes equales, terciadecima lunacione, que incompleta est, totaliter indivisa; cuius tamen partis terciedecime finem in margine sensibiliter signemus intitulaturque pars hec incompleta ultra 12 lunaciones Epacta. Et nota quod quanto fuerit maius spacium inter istum circulum lunacionis & priorem qui est circulus longitudinis cum sua parte duodecima tanto congruentius, dum tamen iste circulus lunacionum non fuerit nimis prope centrum pro suis divisionibus, quia in spacio intercepto describuntur hore lune inequales hoc modo.

Capitulum 17 de horis lunacionis.

Inter intimam circumferenciam circuli exterioris que dicitur circulus longitudinis & extimam circumferenciam huius interioris que est circulus lunacionum, productis diametris orthogonalibus sed occulte a b c d, inueniatur unus circulus contingens ipsas circumferencias ad duo puncta opposita in linea a c ita ut[2] contingat exteriorem uersus a & interiorem uersus c, & fiat iste ecentricus sensibilis; et ubi iste ecentricus dividit lineam diametrabilem d b ponantur puncta d b, & posito centro in g fiat circulus unus occultus transiens per d & b ut patet in presenti figura. Deinde extimam circumferenciam circuli coniunctionis dividemus[3] sic; a principio eius a secundum

[1] 34 minuta, L. [2] uel, both MSS. [3] dividendus, L.

successionem signorum separabimus unum arcum 18 graduum et duorum minutorum, & secundum quantitatem huius partis prime diuidemus totam circumferenciam ad sensibilia puncta ut sint a f g h i k l &c. Nam ista circumferencia sic divisa continebit 24[1] divisiones, excepto quod ultima erit incompleta per 2 gradus, si bene fuerimus operati. Item circulus occultus d b dividatur hoc modo; ab eius principio secundum signa separemus arcum a m 16 graduum & 21 minutorum & secundum illam quantitatem dividamus totam circumferenciam a b occultam ad notas a m n o p q &c. & habebit ista circumferencia tales partes 22 fere. Tercio de extima circumferencia circuli lunacionum ab eius principio consimiliter separemus arcum unum 15 graduum & 9 minutorum & secundum quantitatem illius arcus dividamus totam circumferenciam ad notas a r s t u x y &c. & habebit ista circumferencia tales partes 24 fere. Ut autem absque tedio hos tres circulos dividamus per motus lune in una hora ad hos tres status scilicet ad longitudinem maximam, mediam & minimam, ad quos est motus horarius vel 36 minuta & 4 secunda in proxima, uel est 32 minuta & 42 sec. in media, uel est 30 minuta & 18 secunda in maxima, composite sunt tabule sicut infra dicetur parte tercia, sed tunc de gradibus limbi oportet computare unum signum pro uno gradu & unum gradum pro duobus minutis, & ista divisio redit in idem cum prima. Divisis autem hiis tribus circulis ducatur primo linea una recta patens per eorum principia u a et a. Item invento centro ducatur linea arcualis per[2] tria puncta f m r, et tercia per tria puncta g n s, & quarta per puncta h o t & sic deinceps. Caueatur tamen in fine quod ulla[3] linea horaria non transgrediatur[4] primam lineam horarum que est a a a recta. Post hec abraso occulto circulo d b, scribantur in spaciis horarum littere numerorum horarum sicut in astrolabio solet. Novissimo infra ecentricum Saturni uel ubi commodius poterit fiant duo parvi circuli in quibus signari poterunt auges & gensahar planetarum qui habent auges fixas & gensahar[5]; & completa est prima facies instrumenti.

[1] A writer of the fifteenth century has corrected 24 to 20 and '2 gradus' to '40 min', and rightly. He adds in the margin 'hoc capitulum est falsum fere ex scriptore'. The words '24 . . . operati' really belong to the description of the third circle. The same reader adds 'Nota quod canon hic non concordat perfecte cum operacione infra parte tercia capitulo 19, nec cum tabula velo^tis sue, s[ed] perfecte corrigitur per tabulam magistri Rog[eri]'. There is no alteration in L.

[2] proxima, both MSS.

[3] nulla, L.

[4] transgrediantur, both MSS.

[5] genzahar, L.

Capitulum 18 de inscripcione circulorum in limbo primo[1] *secunde faciei instrumenti.*

Alteram faciem instrumenti iam restat dividere & erit incohacio operis a latitudine limbi l m. Dividamus igitur limbi latitudinem in 3 partes equales cum totidem strictis marginibus & primum marginem dividamus in 360 partes equales, & distribuamus eas in 12 gra[dus], intitulantes ut prius nomina uel numerum signorum cum numero graduum in marginis spacio secundum successionem signorum. Incepcio autem signorum in hoc limbo fiat apud d. Item ab eodem puncto incipiamus dividere secundam marginem per tabulam ascencionum in circulo directo, sed contra naturalem successionem signorum, ab oriente in occidens, a puncto d per c armillam, & dividamus in signa & scribamus ut prius numeros in spacio marginis. Item ab eodem puncto d contra naturalem successionem diuidemus terciam marginem cum suo spacio per tabulam ascensionum ville vel climatis ubi magis intendimus commorari & consideracionibus magis uti, & spacium huius marginis intitulabimus nominibus & numeris signorum & graduum, sicut sepe dictum est, & completum est.

Capitulum 19 de composicione circuli involuti. [Fig. 12

Laminam interiorem r o s postea dividemus hoc modo; primo separabimus brevem marginem cum spacio. Deinde, ipsa lamina immobiliter loco fixa, producemus occulte diametros orthogonales a c & d b super centrum o & super 4 centra in diametris accepta prope faciemus unum circulum involutum 32 revolucionum hoc modo. Prope o in diametro a c signentur duo centra altrinsecus e f, in quorum medio equidistanter sit o centrum. Item in linea d b signentur alia duo centra equidistanter ipsi o, qui sint g i, ita quod in eadem linea sint consequenter puncta d g o i b & in altera a e o f c; hoc modo apud b accipiatur una linea que sit b h, quantum sufficit ad latitudinem unius spacii circularis cum suo margine & dividamus ipsam lineam in 4 partes equales & a prima divisione prope b accipiatur linea uersus o equalis linee b o, cuius terminus sit g; erit g distancia 4 centrorum f g e i a centro o equalis distancie linee g o. Deinde posito pede circini in centro i extendatur alius pes a d b & circumducatur usque ad semidiametrum o c ad punctum k. Item posito centro in f & alter pes circini ponatur in k & circumducatur usque ad semidiametrum d o, terminans in punctum l prope d. Item

[1] limbo secundo, L.

posito centro in g & altero pede in l, circumducatur usque ad semidiametrum o s in punctum m. Item posito centro in e circumferatur alter pes usque ad semidiametrum o b, & iste vocatur unus circulus involutus; tales revoluciones involutas faciamus 32 & super eisdem centris, constricto modicum circino marginabimus eas & completum est.

Conclusio 20[1] *de arte componendi circulum involutum.*

Circulus involutus continebit medium motum anni Mercurii et medium motum anni lune & medium ⟨motum⟩[2] ar^ti^ lune; ideoque primo dicamus de descripcione medii motus Mercurii. Inchoantes igitur in prima revolucione apud d, dividamus illam continue per tabulam medii motus Mercurii expansam ad dies singulos anni solaris, scilicet ad 365 dies & ultra quantum est eius motus ultra in residuo anni, scilicet 6 hore fere, que tabula ponetur in parte huius tercia inter ceteras tabulas. Ponemus autem omnes divisiones in margine & sex[tam] & sextam in spacio marginis; & tunc distribuemus illos 365 dies in menses, dando cuilibet mensi dies suos inchoando a mense Ianuario vel Marcio sicut in aliis, & continebit ultimus mensis ultra dies illud superfluum quarte diei fere & completum est.

Capitulum 21 de inscribendo medio motu lune.

Ad inscribendum medium motum lune in residuo circuli involuti, primo ammoveamus laminam r o s de loco suo fixo & ponamus ultimam divisionem circuli anni Mercurii in directo contra punctum d & tunc consolidemus laminam r o s in loco illo & incipientes a puncto quod est in directo d, dividamus circulum involutum continue per motum lune in singulis diebus anni & ultra quantum superfluit annus ultra 365 dies, & ponas has divisiones in margine involuto & similiter in margine illo facto in limbo lamine f o r,[3] nondum diviso. Deinde quamlibet divisionem factam in illo margine extimo dividemus in 24 partes equales, & erunt hore motus lune, & spacium marginis involuti dividemus per binos & binos dies & in directo dierum scribemus in spaciis numerum dierum & literas feriarum & nomina festorum secundum commoditatem instrumenti, ne confusio sed pocius distinctio[4]

[1] Capitulum 20, L. [2] L. [3] s o r, L.
[4] distincte, MSS. A note of the fifteenth century, partly cut off, in the margin 'Hoc est imponas regulam super quamlibet divisionem in circulo involuto medii lune & extendas ad marginem extimam lamine & ita dividas marginem & semper correspondebunt

appareat manifesta, & cum hoc perfectum fuerit, iterum amovebimus laminam r o s & ponemus finem anni lunaris contra d & ibi incipiemus dividere residuum circuli involuti per tabulam ar^{ti} lune omnino sicut dictum est de medio motu lune, fiatque apparens signum ubi incipit primus mensis motus lune & ar^{ti} lune & completum est.

Capitulum 22 de climate & almicantarath.

Vertamus laminam r o s & consolidemus eam in loco suo. Deinde separemus de limbo eius unum marginem cum unico spacio & dividemus marginem eius in 12 signa & gradus equales & intitulabimus eius spacium ita quod caput capricorni sit apud a & capud arietis sit apud d cum successu & contra naturalem successum signorum. Deinde patenter productis diametris a c b d extrahatur ab intimo circulo arcus 30 graduum computando ab a uersus d. Deinde posita regula in b linea a puncto b usque ad finem arcus 30 graduum, ibi ponatur e. Deinde ubi linea b e abscindit semidiametrum o a ponatur nota f., fiatque circulus secundum quantitatem semidiametri o f, qui erit vice circuli equinoxialis. Deinde per artem traditam in operacione astrolabii extrahatur linea ecliptica, cuius arcus meridionalis sit uersus punctum a & arcus septentrionalis uersus c & fiat ecliptica sensibilis atque patens. Deinde extra eclipticam fiant sex circuli subtiles ostendentes latitudinem sex graduum meridionalium & totidem circuli fiant intra eclipticam ostendentes latitudinem sex graduum septentrionalium. Deinde dividatur sola ecliptica per ascensiones in circulo directo, & invento polo ecliptice per totam declinacionem a polo equinoxiali o, qui polus ecliptice sit g, inveniantur circuli qui possunt transire per polum g & per singulam divisionem ecliptice & eius nadir & sensibiliter divident isti circuli totam latitudinem zodiaci, & non appareat quicquam amplius de illis circulis. Deinde fiat orizon & clima illius latitudinis, cuius ascenciones scribuntur in limbo armille l m & fiant perfecte azimuth & almuchantarath ita tamen quod non confundant nimis gradus zodiaci in longitudine & latitudine, nec appareat quicquam in circulo equinoxiali aut de tropicis nisi sub almucanterath inter lineas horarum, & completum est.

divisiones exteriores interioribus & e contra; nec oportet quod inscribas numeros in illis divisionibus limbi, quia non semper in operando correspondebunt numeri horarum ibi inscribendarum horis dierum involutarum, quia accidit aliquando ubi inscriberetur in limbo 24, esset in die involuta hora 16^{a}, & hoc propter id superfluum quod addit annus ultra 365 dies.

Capitulum 23 de eodem.

Si autem placuerit habere plures tabulas climatum, faciamus illas omnino sicut dictum est uno addito quod in limbo eiusdem lamine oportet in loco circuli zodiaci eius vel cum illo inscribere eciam ascensiones eiusdem climatis ad quod illa tabula perficitur, & non est opus habere rethe stellarum in isto opere sed imprimantur stelle et eorum nomina in singulis tabulis climatum. Sed excedit hoc opus astrolabium in facilitate operandi & precisione & superaddit quedam, quia cum hoc operari possumus cum omnibus stellis erraticis de nocte equifaciliter sicut cum stellis fixis, quod non contingit in astrolabio sicut patebit.

Capitulum vicesimum quartum de Saphea.

In fundo eciam medie lamine perficere possumus instrumentum saphee quod est quasi astrolabium uniuersale vel saltem ad abreviandum difficultatem operis in saphea; factis circulis ascensionum & revolucionum saphee, extrahi poterit orizon certi climatis & cenith capitis & per equidistantes lineas orizanti usque ad cenith capitis, quod est polus omnium illorum, & per lineas quotlibet exeuntes a cenith cadentes orthogonaliter super orizontem perficere poterimus almicanterath & azymuth eiusdem climatis; & erit eius operacio expedita ad horas diei & noctis & mirabiliter manifesta. Et si placuerit, sub illo orizonte obliquo signari poterit orizon non multum obliquans a priori & eius polus extrahi poterit in parte opposita quasi in angulo terre & perficere poterimus almuchantarath & azimuth secundum exigenciam huius orizontis & cenith capitis, & sic in eadem superficie satis comode habebimus quasi duo climata & marginentur eorum orizonta & circulus zodiaci distincte & apperte, & non erit confusio quamvis multi circuli condense sese intersecent. Qui autem conceperit artem componendi sapheam de facili potest ista concipere & ideo non est opus hic diucius immorari circa exemplarem descripcionem istorum. Ita igitur fiat & completum est.

Capitulum 25 de linea corde recte & linea minutorum dividenda. [Fig. 13

Vertamus insuper laminam p g q & consolidemus eam in loco suo, quia ex parte hac describimus circulos eclipsium solis & lune, & primo perficiamus in ea lineam corde recte & uerse hoc modo. Productis diametris orthogonalibus a g c & b g d perficiamus marginem cum spacio equidistanti diametro a c, iam c[apitulo] secundo inceptum. Deinde totum

diametrum medii circuli & communis[1] duobus marginibus limbi primi, scilicet circuli altitudinis & zodiaci octave spere dividemus in 60 partes equales & eius spacium per quinos & quinos gradus & quamlibet partem illarum 60 dividamus ad minus in tres partes uel quot minuta fuerit possibile & intitulabimus in spacio illos gradus dupplici numero quorum unus incipiet a c uersus a, & alter ab a uersus c, & erit uterque numerus 60, nec omnino transeat aliquis circulus per hanc lineam cordarum ne confundat eius diuisiones omnino. Deinde posito circino in centro communi g de medietate diametri iam divisi accipiamus lineam 21 graduum & 20 minutorum & secundum illam quantitatem resecabimus de utraque parte alterius diametri orthogonalis, & marginabimus illud altrinsecus cum spacio ad instar posterioris & utraque illarum parcium g d & g b dividemus in 64 partes equales, & spacium eius per 5 & 5 inscribendo numeros, incipiendo a centro g uersus b & uersus d; & completum est.

Capitulum 26 de figura eclipsis lune scribenda. [Fig. 14

Circulum eclipsis lune perficiamus hoc modo. Posito centro in g extendatur alter pes super alteram linearum divisarum per 60 partes equales usque ad 63 partes & 36 minuta & secundum illam quantitatem fiat semicirculus d e b super centrum g, nullo tamen modo confundat eius transitus divisiones signatas in linea c a, divisa in 60. Item super idem centrum fiat alter semicirculus f h i, ita quod tam g f semidiameter quam g i sit 52 partes & 50 minuta de eisdem partibus. Deinde divisa linea d g i in duas partes equales & in eius medio facto centro, ducatur semicirculus d k i contingens utrumque duorum semicirculorum priorum. Post hec extra circulum d e b perficiamus primo marginem prope d e b, & deinde spacium & eius margine[m] dividamus hoc modo; super semidiametrum g a divisum in 30 partes equales quarum quelibet similiter est divisa in 3 partes que sunt minuta 20, scilicet pars tercia unius gradus, extendatur regula orthogonaliter super quamlibet partem 20 minutorum, & ubi hec regula contingit semicirculum d e b signetur punctus ex utraque parte; quinta[2] tamen divisio transeat super totum spacium quod est inter duos semicirculos d e b & f h i, usque quod totus semicirculus d e b fuerit per talia puncta divisus & spacium quod est inter duos semicirculos predictos per lineas rectas, que non extendantur ultra spacium inter dictos semicirculos interceptum. Post hec posita regula in centro communi g, transeat per quemlibet punctum signatum in

[1] L. inserts hiis after duobus. [2] hec, L.

semicirculo antedicto d e b, & dividamus marginem antedictum operacione[1] communi, quarum quinta & quarta divisio

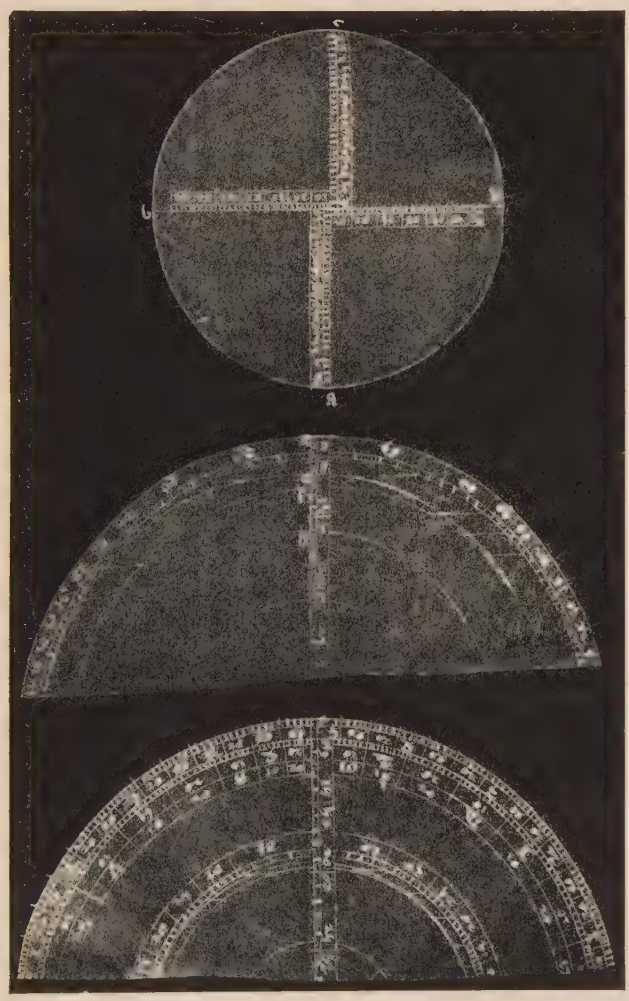

Fig. 13.

Fig. 14.

Fig. 15.

ultra extendatur per spacium pro litteris assignatum. Deinde de semidiametro g d capiatur linea 45 parcium & 56 minu-

[1] operacioni, MS.

torum que sit linea g l.[1] Item de linea g b capiatur altera linea 38 parcium & 10 minutorum que sit linea g m, & super lineam l m perficiamus semicirculum. Item de linea g d capiamus lineam 28 gra' 16 min' que sit linea g n; alteram eciam lineam g o de linea g b que sit 23 parcium & 30 minutorum, & perficiamus semicirculum super lineam o n, & completum est.

Capitulum 27 de arte componendi circulum latitudinis lune.

Post hec super spacium alterius semicirculi d e b, perficiamus circulum latitudinis lune hoc modo. Prope limbum eiusdem separemus unicam marginem cum unico spacio & dividamus eius marginem in 10 partes equales, que erunt gradus & quamlibet illarum parcium in 60 minuta, & posita regula super commune centrum g dividamus marginem per singulas divisiones & spacium per 5 & 5 vel per 6 & 6 modo communi, & intitulabimus ipsas divisiones graduum, a puncto d uersus c, similiter a puncto b uersus c & habebit utraque quarta circuli 5 gradus & quilibet gradus 60 minuta. Deinde separabimus consequenter unam marginem cum duobus spaciis & ipsam marginem modo communi dividemus per tabulam latitudinis lune. Postea incipientes a puncto b uersus d distribuamus priori spacio gradus per 6 signa & iterum redeundo a puncto d uersus b intitulabimus residua 6 signa, uidelicet a septem usque 12; nullo tamen modo transeat aliqua harum divisionum aut circuli super divisiones diametrorum ne forte confundentur; quia necesse est eas esse distinctas; & completum est.

Capitulum 28.

Novissimo compleamus figuram eclipsis solaris hoc modo. Primo super centrum g fiat unus circulus ultra semicirculum latitudinis lune, cuius semidiameter g p contineat 34 partes de partibus linee g d, & alium semicirculum cuius semidiameter g q contineat 31 partes, & divisa linea p q in duo equalia fiat super ipsam semicirculus p r q contingens utrumque semicirculum antedictum. Deinde extra semicirculum p concentricum faciamus marginem & spacium & dividamus eas per regulam iacentem orthogonaliter super semidiametrum g c[2] & transeuntem super singulas tercias unius gradus omnino sicut dictum est de figura eclipsis lunaris. Postea posito centro in g fiat alter semicirculus cuius semidiameter contineat 16 partes & 20 minuta, ut g s, omnino sicut patet in presenti figura & completum est.

[1] g b, L. [2] g o, L.

Capitulum vicesimum nonum. [Fig. 15

Tandem perficiamus paxillum qui possit transire super centrum g per medium totius instrumenti ad constringendum utrasque tabulas instrumenti cum rethi, sicut in astrolabio, excepto quod non erit illi equus nec aliqua pars multum supereminens super superficiem laminarum. Sed erit illi firmamentum hoc modo. Ex una parte instrumenti habeat paxillus capud subtile non multum supereminens sed sufficiens ad constringendum laminam cum matre; ex parte altera fiat una concavitas in paxillo prope superficiem alterius faciei instrumenti in circuitu eius, ut possit recipere tenuem laminam; hoc modo coniungantur due breves lamine circulares in medio perforate, ita quod possent recipere ipsum paxillum; inter illas breves laminas comprehendatur alia tenuis lamina semicircularis, firmata tantum cum una clavi ita quod possit extrahi per eius motum tanquam in cardine extra locum suum inter illas duas laminas breues, & habeat in eo diametro concavitatem qua possint applicari ad paxillum in concavitate paxilli & ipsum retinebit paxillum & constringet alteram laminam ac si foret alterum capud paxilli & hec erit forma istius capitis sive firmamenti ex hiis tribus partibus compositum; habeatque ipsa media lamina circularis unam superfluitatem prominentem, qua possit faciliter extrahi de loco suo cum voluerimus separare laminas instrumenti ab invicem; & perforemus paxillum veraciter super centrum eius g ita quod filum possit pertransire per medium eius ex utraque facie instrumenti & completum est.

Capitulum 30 & ultimum secunde partis.

Cum ista perfecerimus, aptemus armillam unam suspensoriam sive portatilem & in circulo illo tercio communi duabus marginibus circuli altitudinis & zodiaci primi limbi apud c faciamus foramen & firmabimus ibi filum cum perpendiculo ad capiendum altitudines & per utramque pinnulam perforatam & ad perficiendum alia opera ad quod institutum est, sicut loco suo docetur, & completum est hoc opus cum adiutorio dei anno Cristi 1327 inchoante.

Incipit pars tercia de modo operandi per instrumentum.

NOTE

On fol. 1v of MS. Laud 657 is a note written in the same hand as the MS.

Sciendum est quod dominus Ricardus abbas monasterii sancti Albani primo composuit istum librum, & per eum

excogitauit & fecit instrumentum illud mirificum quod dicitur Albeon, sed postea quidam Symon Tounstede, sacre theologie professor, quedam mutauit tam in libro quam in instrumento, sicut patet studentibus in libro isto, quedam eciam superaddidit.

Hunc librum dedit dompnus Iohannes de Westwyke deo & beate Marie & sancto Oswino regi & martiri de Tynemouth & monachis ibidem deo seruientibus.

Mr. Salter is of opinion that MS. Laud 657 on the Albion is copied from MS. Corpus 144, but that Part iii of the Laudian MS. is original. It gives 32 'utilitates' of the Albion. The pars quarta is de modo operandi, corresponding to the pars tercia of the Corpus MS.

C. THE TURQUET

Printed from MS. Ashmole 1522

See p. 35

[f. 176] *De tabula turketi que dicitur orizon deseruiente equinoctiali.*

De omnibus parcium instrumenti quod turketus dicitur primo ; postea de utilitatibus est dicendum. Prima pars est tabula recte quadrata equinoctiali deseruiens in qua est circulus diuisus in 360 gradus, cuius centrum est polus mundi et .4. semidiametra ab eodem centro exeuncia ad extremitatem tabule que .4. plagas mundi terminant, ita quod sinistra oriens, dextra occidens, in ante meridiem, in retro mediam noctem designant. Et latus huius tabule cui linea meridiana incidit orthogonaliter eleuabitur et deprimetur secundum altitudinem equinoctialem in regione. Latus uero oppositum cui linea medie noctis instat orthogonaliter erit affixum duabus auriculis cuidam tabule lignee plane et eque spisse exeunti in superficie orizontis, et dicitur hec tabula orizon.

De basilica et orbe signorum sibi affixo.

Secunda pars eius est corpus quoddam, quod *orbis signorum* dicitur. In cuius base est tabula quadrata, dyametrata duabus dyametris orthogonaliter se secantibus in quodam puncto, quod centrum mundi siue polus dicitur,

que tabula basilica dicitur; et hec tabula *basilica* tabule equinoctiali coniungitur mediante clauo transeunte per polos mundi utriusque tabule fortiter cuneato ita quod motus basilice super tabulam equinoctialem sit difficilis; et almuri quidam denticulus egredietur a medio meridiani lateris basilice a directo linee meridiane super gradus tabule equinoctialis cuius officium omnino est hic vt in astrolabio. Super .2. latera eiusdem basilice ad orientale videlicet et occidentale orthogonaliter erecte sunt .2. tabule equales totam solis declinacionem rectissime continentes. ¶ In summitatibus quarum affigitur tabula rotunda equalis spissitudinis bene polita que ecliptica siue zodiacus dicitur, siue orbis signorum, [f. 176v] continens .12. signa, cum suis gradibus et .12. menses cum suis diebus sicut in dorso astrolabij continetur, dyametrata duabus dyametris se orthogonaliter in centro eius quod polus zodiaci dicitur secantibus, ita quod dyameter transiens a principio arietis in libram coluro equinoctiali, et a principio cancri in capricornum coluro solsticiali deseruiant; et hec dyametra zodiaci fiunt in directo dyametrorum basilice, ita quod punctus cancri sit in suprema declinacione et e directo almuri et punctus capricorni in inferiori.

De allidada siue turno et circulo magno sibi affixo.

Tercia pars instrumenti est *allidada* quadrangula fortis et eque spissa; et dicitur allidada zodiaci siue *turnus* proprie cuius media linea mediatrix siue linea fiducie dicitur habens .2. latera utriusque equedistanter mediatrici lineata; extremitates vero mediatricis acuate sunt ut in allidada astrolabij; supra quam due sunt pinnule ut in astrolabio, per quarum foramina siue semiforamina radius solaris semper transibit. ¶ Super hunc turnum tabula rotunda plana in .360. gradus diuisa orthogonaliter erigitur, ita quod superficies ipsius diuisa sit in directo linee mediatricis turni e directo poli zodiaci vicem axis zodiaci optinens; alia dyameter sit equedistans superficiei zodiaci tabule signorum vicem habens ecliptice ita quod superior pars septemtrionalis inferior australis vocetur, et vocetur hec tabula circulus magnus siue longitudinis, habens allidadam cum pinnulis que allidada circuli magni dicitur.

De .4a parte turketi que semis dicitur. [See p. 37.

Qvarta pars huius instrumenti est *semis* rectissime quadratus habens .4. latera, dextrum, et sinistrum, proximum dextro, et proximum sinistro et perpendiculum ex filo, et melius ex corpore graui. Continebit autem quadrans iste

quartam partem circuli, diuisam in .90. gradus, [f. 177] que sic fit. Fiat tabula una semicirculum continens, cuius dyameter siue axis sit *.a. b.* dimidia circumferencia *.a. c. b.* diuisa super centrum *.d.* in .180. gradus. Sitque semidyameter, equans *.d c.* diuidens eam per equalia et dicatur hec semidyameter equans ; et in extremitatibus dyametri *.a.* et *.b.* sint due auricule rotunde, ita quod *.a b.* recte transeat per medium ipsarum ; per quas auriculas eadem tabula duobus foraminibus in pinnulis allidade circuli magni qui crista dicitur equidistanter linee fiducie perforatis immittatur. In puncto vero *.d.* filum pendeat perpendiculum cum margarita sicut est in quadrante, et hec tabula semis vocatur. In qua construantur linee horarie ut in quadrante ; et hec tabula semis deseruit totidem uel pluribus utilitatibus quam faciat quadrans quadratus ; vnde in hoc opere quadrans est superfluus.

De vtilitatibus turketi et primo de situacione eius in qualibet regione.

Cvm uti uolueris instrumento hoc, primo situabis ipsum in regione tua sic. Aptabis aream planissimam equidistantem orizonti, de plaustro uel de ligno, in qua constitues lineam meridianam ; cui coapta lineam meridianam instrumenti ; et uide quod recte facias. Tunc aree predicte affigas tabulam ligneam que orizon dicitur affixam tabule equinoctiali ita quod de cetero amoueri non possit ; et uide quod aures equinoctiales fuerint equidistantes orizonti. Posita allida [*sic*] cum semisse super eclipcam [*sic*] criste et allidada turni super circulum equinoctialem e directo orientis et occidentis equinoctialis si perpendiculum cadat super equantem semissis est equinoctialis equidistans orizonti. Sin autem, rectifica donec sit aptum posita allidada cum semisse ut prius ; [f. 177^{v}] super circulum equinoctialem e directo meridiani tabule equinoctialis recte ad meridiem eleua equinoctialem, donec perpendiculum distet per gradus altitudinis arietis in regione tua. Tunc equinoctialem sustenta uel subpodia stilo subfixo equinoctiali ; et hic erit situs turketi perpetuus in regione tua. Vel aliter pone allidadam zodiaci super turnum, super gradum solis in orbe signorum, regulam infrascriptam inuentam. Deinde eleuabis equinoctialem per semissem ut dictum est secundum altitudinem equinoctialem. in regione tua et suppone ut predictum est. Deinde gradum solis cum turno uersus solem orientem uel occidentem, ipso tamen turno cum gradibus solis sic disposito per semissem quod equidistet orizonti, verte inquam gradum solis donec radius solis intret per ambo foramina allidade ; quo facto situatum est instrumentum pro regione tua ; confige ergo ipsum clauis fortiter aree.

De gradu solis inueniendo.

Pone allidadam zodiaci siue turnum super diem mensis in quo es et summitas eius in orbe signorum gradum solis ostendet. Eodem modo per gradum solis diem mensis habebis.

De altitudine solis inuenienda.

UErte turnum super gradum solis positum ad solem, donec radius solis per ambo foramina pinnularum ingrediatur. Deinde applica latus quadrantis lateri turni cui poteris commodius. vide gradus perpendiculi inter semissem et equantem qui ostendet [*sic*] altitudinem solis ad istud instans. Eodem modo fac ad meridiem. et ad aliam omnem partem celi. Et sic habebis altitudinem solis ad omnem horam.

De figura celi uel orbis signorum habenda.

UErte gradum solis cum turno ad solem, donec radius solis ingrediatur per ambo foramina et habebis figuram celi uel figuram orbis signorum ad illam horam. Eodem modo inuenies figuram celi per stellas notas ad omnem horam per modum infra scriptum.

De inuencione ascendentis.

INuenta figura celi per solem uel per stellam applica latus quadrantis lateri turni et eleua, vel deprime turnum tantum donec perpendiculum quadrantis cadat super alterum laterum quadrantis dextrum uel sinistrum rectissime, et summitas turni a parte orientis dabit gradum ascendentem, [f. 178] et a parte occidentis gradum occidentem; gradum uero medij celi dabit latus quadrantis exiens a linea meridiani equinoctialis orthogonaliter.

De arcu diurno uel nocturno.

UErte gradum solis cum turno ad oriens deprimendo vel eleuando eum donec perpendiculum cadat super equantem certissime; et notes almuri in equinoctiali; et hec est nota eius ad ortum solis. Deinde volue eundem gradum solis cum turno eleuando uel deprimendo totum orbem signorum cum turno, donec iterum perpendiculum cadat super eundem equantem rectissime; et notes gradum almuri in equinoctiali; et hec est nota eius ad occasum solis; et gradus equinoctialis pertransiti per almuri ab vna nota in aliam est arcus diurnus et gradus residui est arcus nocturnus. Eodem modo facies de stellis, quos, si diuiseris per .15. habebis partes

horarum diei uel noctis; et si diuiseris per .15. habebis horas equales eorundem, scilicet diei uel noctis.

De horis diei uel noctis preteritis.

Pone almuri super notam eius ad ortum solis. Deinde volue totum orbem signorum cum turno donec ingrediatur radius solis per ambo foramina, et notes almuri; et hec est nota eius ad instans. Deinde diuide gradus almuri pertransitos a nota ortus solis ad notam instantis per partes horarum illius diei, et habebis horas diei inequales transactas, vel per .15. et habebis horas equales transactas. Eodem modo facies in nocte et intra quaslibet notas. Eodem modo habebis horas in semisse inequales ut in quadrante, posita allidada cum semisse, super eclipticam criste, et turnum cum gradu solis tam diu volues uersus meridiem, donec ad plus distet perpendiculum ab ecliptica, et vbi perpendiculum intersecauerit finem 6ᵉ. hore, pone margaritam et habebis horas naturales diei, ante uel post meridiem in quadrante.

De uerificacione et loco stellarum fixarum et erraticarum in longitudine et latitudine.

Si vis uerificare loca stellarum erraticarum vel fixarum tam in longitudine quam in latitudine, supposito quod gradus solis sit bene certus, hoc modo procedes; fac figuram celi ad occasum solis rectissime et notes almuri ad eandem horam. Deinde volue solummodo turnum sine orbe signorum ad locum lune respiciendo [f. 178ᵛ] per foramina allidade circuli magni, eleuando uel deprimendo donec lunam uideas per ipsa; tunc summitas turni in circulo signorum dabit gradum longitudinis lune certissimum ad horam occasus solis; serua ipsum. Summitas uero allidade circuli magni a parte lune ostendet latitudinem eius ab ecliptica; quot enim gradibus distiterit ab ecliptica circuli magni in septemtrionem uel in australem, tanta erit latitudo eius a via solis sine dubio cum diuersitate aspectus lune. Si enim distiterit ab ecliptica circuli magni in partem superiorem quidem circuli magni est latitudo septemtrionalis; set in partem inferiorem est australis. Eodem modo fac et in stellis alijs; gradus uero inter perpendiculum et equantem sunt altitudo lune uel stelle. ¶ Deinde cedat tempus sensibile et fac figuram celi per locum lune predictum ad istud instans, et notes almuri ad istud instans. Quod si gradus deambulacionis almuri a nota almuri ad occasum ad notam eius ad instans sint .15. gradus adde dimidium gradum super locum lune inuentum

ad occasum solis; si bis 15 vnum gradum et sic in alijs; et habebis certum locum lune ad horam instantem. Per illum igitur gradum lune fac figuram celi et volue turnum tantum modo sine orbe signorum ad stellam quam verificare vis secundum modum iam dictum in luna, et habebis verum gradum longitudinis stelle et latitudinem eius et partem latitudinis eius si deus voluerit; pone ipsam in tabulam stellarum et serva. Eodem modo facies de alijs stellis fixis et similiter de planetis; et scies certissime in quanto errant tabule tholetane, uel aliarum ciuitatum a veris locis ipsarum; et hoc aduerte. Modum autem verificacionis tabularum predictarum alias exponam nutu dei. ℭ Altitudinem quoque stellarum et declinacionem ipsarum et partem declinacionis et figuram celi et ascendens et arcum diurnum earum et nocturnum et horas noctis preteritas equales et inequales, et alia quamplura, sagax lector facile per se inueniet ex predictis. Deo gratias. Explicit.

D. NAVICULA DE VENETIIS

Printed from MS. Bodl. 68 (= S.C. 2142) *which formerly belonged to John Enderby of Louth, priest, at the end of the fourteenth century*

See p. 40

[f. 35r] [A]D constructionem nauicule de veneciis, tria ad minus sunt instrumenta valde necessaria. Que sic fiant. Capias circinum et disiunge pedes ad mensuram dimidij pedis et pungas .3. puncta fideliter in triangulum in .3. laminis de auricalco signando ipsa puncta cum .3. litteris .A. B. C. Deinde ponas pedem vnum circini in puncto .A. et cum altero pede describe arcum a puncto .B. vsque in punctum .C.; hoc in 3. laminis facto redeas ad primam, et a punctis .B. C. protrahe lineas ad punctum .A. et sic habes .6. partem circuli. Tunc diuidas arcum .B. C. in .60. gradus equales, de quibus .24tus. gradus ab angulo .B. atque omnes alij ab ipso vsque in angulum .C. habebunt lineas suas vsque in centrum .A.; de ceteris gradibus vsque ad primam lineam que est linea declinacionis sufficit quod 5tus. gradus habeat lineam suam ad centrum .A.; hoc facto erige lineam per angulos rectos a medio puncto linee .A. B. vsque in punctum .C. deinde pone pedem vnum circini immobilem in puncto .A. et alium pedem in pede illius linee ortogonaliter erecte et protrahe arcum modicum

vsque in lineam declinacionis; super cuius contactum erigas ortogonaliter aliam lineam cum arcu suo vt prius. Et sic de alijs quot volueris pro nauiculis maioribus vel minoribus. Et sic habes declinacionem solis et gradus latitudinum sufficientes pro tota terra bone habitacionis. Qui voluerit plures gradus addere pro remocioribus terre partibus [f. 35v] addat in nomine domini.

Post hoc sequitur de alijs instrumentis pro figuris signorum prius inceptis. In quibus facies lineam a centro .A. per medium arcus .B. C. vsque ad terminum lamine que vocetur linea equinoctialis. Tunc capias cum circino declinacionem solis videlicet spacium .24. graduum de priori instrumento, et punctues eam fideliter in vtraque parte equinoctialis in arcubus istorum, que puncta vocentur puncta solsticialia; super que puncta facies lineam occultam ab vna parte laminis in aliam; et sic habes in equinoctiali duas intersectiones, que signentur cum litteris D. E. Tunc ponas pedem vnum circini in puncto .D. et cum altero pede formes semicirculum ab vno puncto solsticiali vsque in aliud. Omnibus hijs in vtroque instrumento factis, capias vnum istorum per quod philum cum nodulo regetur; et pone vnum pedem in puncto .E. et moueas alterum pedem vsque ad vlteriorem partem semicirculi; cum quo pede ducas circumferenciam ab vna parte occulte linee vsque in aliam. Adhuc pedibus circini non motis capias aliud instrumentum per quod malum nauicula regetur; et pone vnum pedem circini in vno puncto solsticiali et cum alio pede facias punctum pro centro in linea occulta; in quo centro pones pedem vnum immobilem et cum altero pede deduces arcum a puncto solsticiali vsque in equinoctialem. Et sub eadem forma facies consimilem arcum in parte altera. Tunc isti arcus cum exteriori linea circumferenciali alterius instrumenti diuidantur in .6. partes equales. Quarum due partes [f. 36r] iuxta solsticia diuidantur in .3. partes equales. Omnes alie partes diuidantur in .6. partes equales. Hoc facto omnes iste diuisiones vtriusque instrumenti ducantur interius vsque in semicirculum cum regula versus centrum .D. Deinde ducantur cum regula et gnomone a semicirculo in arcu .B. C. hoc modo. Confirmes regulam super laminam extra arcum .B. C. cum duobus forpicibus ita vt vnum latus gnomonis concordet regule, et aliud equinoctiali. Tunc moueas gnomonem super regulam per notas in semicirculo; et notes eas in arcu predicto et hoc cum occultis lineis interius vt postea poteris eas cum regula a centro .A. apercius notare exterius. Iste figure zodiaci facte sunt secundum formam astrolabij, et non quadrantis. In quadrante quilibet gradus tenet locum proprium secundum quod discat ab equinoctiali. In astrolabio

.4. gradus cardinales tenent sua propria loca et non plures, sicut hic in istis figuris ; alij gradus extrahuntur a locis suis, videlicet in figura mali trahuntur interius versus equinoctialem. In figura phili et noduli trahuntur exterius versus puncta solsticialia, quod prouenit ex magnitudine paralellorum iuxta equinoctialem.

Post hoc facies vnam vel duas figuras pro lineis horarijs inueniendis hoc modo. Ponas pedem vnum circini in centro .A. primi instrumenti, mouendo alterum pedem quousque recte fuerit in pede breuioris linee latitudinum ; per quam mensuram describes super lineam rectam semicirculum in dorso eiusdem instrumenti. [f. 36v] Deinde ducito lineam a centro in medium punctum .F. Tunc vterque arcus in vtraque parte .F. diuidatur in .6. partes videlicet in .6. horas equales; quarum .4. prime diuidantur in .3. partes equales, una diuidatur in .2. partes equales, et .6. non diuidatur. Tunc omnes iste diuisiones simul trahantur cum rectis lineis ab vna parte in aliam ; et sic habebis in semidiametro veram disposicionem linearum horariarum pro nauicula illius quantitatis. Iterum redeas ad primum instrumentum et pone pedem circini in centro .A. vt prius, et moueas alterum pedem quousque recte fuerit in pede maioris linee latitudinum. Deinde pedibus circini non motis, pone vnum pedem in puncto .F. et vbi alter pes intersecat primam lineam, fac ibi punctum; et ab vno puncto in aliud trahas lineam ; super quam lineam capias lineas horarias pro maiori nauicula. Eodem modo facies de .3. et .4. linea latitudinum. Pro .5. et alijs maioribus lineis, facias aliam figuram vt prius, ita vt quelibet linea latitudinum habeat in istis figuris lineam sibi conformem maxima linea solummodo excepta.

Cum volueris nauiculam componere, primo elige tibi lineam latitudinum ad quantitatem nauicule tue competentem ; deinde capias cum circino distanciam pedis eius a centro .A., per quam mensuram describes principalem nauicule circulum, relinquens spacium modicum extra pro figuris signorum. Per cuius centrum ab vna parte in aliam deduces lineam equinoctialem ; et ab eodem centro per medium semicirculi deduces lineam perpendicularem que erit linea hore .6. Et sic habes in circulo .3. intersectiones [f. 37r] in quibus facies .3. puncta equinoctialia. Tunc redeas ad lineam latitudinum et capias subtiliter quantitatem arcus eius que est declinacio solis et punctues eam sexies in predicto circulo, videlicet in vtraque parte .3. punctorum equinoctialium. Que puncta vocentur puncta solsticialia. Super que puncta trahes duas lineas, videlicet vnam in parte posteriori pro hora .12. noctis aliam in parte anteriori pro hora .12. die[i]. Tunc capias in-

strumentum factum pro regimine phili et noduli, super quod compones nauiculam ita vt concordent centrum cum centro, equinoctial*is* cum equinoctiali, solsticia cum solsticialibus; et sic simul teneantur cum duobus forpicibus quousque fideliter extraxeris cum regula versus centrum nauicule figuram signorum ab vna lamina in aliam. Hoc facto disiungas laminam illam a nauicula et coniungas aliam et notes figuram illius in parte inferiori pro gubernacione mali per omnia vt prius. Postea facies duas lineas occultas ab vna parte nauicule in aliam, videlicet in vtraque parte equinoctial*is* vnam, ab ea equedistantes. In quibus notabis lineas horarias sic. Queres in semicirculis prius factis lineam huic nauicule conformem in cuius contactu super maximam semicirculi lineam, que est in nauicula linea hore .6., pone pedem circini, mouendo alterum pedem quousque recte fuerit in proxima intersecione; quam punctues quater in lineis occultis, videlicet in vtraque parte linee hore .6. Eodem modo facias de omnibus alijs quousque perfeceris. Tunc super ista puncta trahas lineas pro horis longiores, pro alijs breuiores, vt hore pre alijs melius videantur. Latitu[f. 37v]dines similiter de linea latitudinum transferantur in malum. Aures cum foraminibus equedistent omni modo ab equinoctiali; et sic eleuentur supra puncta solsticialia vt non impediant philum. Malum similiter in equinoctio ab vtroque puncto solsticiali equedistet omni modo.

In hoc instrumento nauicule, due zodiaci figure adminus sunt necessarie, videlicet vna in ymo pro gubernacione mali, altera in parte anteriori pro gubernacione phili et noduli; vtraque figura .6. continet signa; quodlibet signum .30. continet gradus, per partes eiusdem signi equaliter diuidendos. Extremi gradus huius figure dant solsticia, medius vero equinoctia. In longioribus lineis a summo vsque deorsum perpendiculariter protractis cum crucibus in summitatibus earum signatis hore inicium habent et finem. Ex istis lineis tres sunt punctuate vt cicius videatur quota sit linea ab vna parte vel ab alia; quarum media ab vtraque parte semper est sexta; vtraque aliarum duarum a parte propiori est tercia, et a parte remociori est nona. Breuiores linee intercepte horas diuidunt in partes binas vel trinas. Per gradus latitudinum in malo, aptare poteris instrumentum ad quamcumque volueris regionem. Cum volueris horam diei inuenire, primo videas quod .12. signa sint in kalend*ario* tuo fideliter posita; deinde videas distantiam solis ab equinoctio vel solsticio in signo et gradu, et ibidem ponas malum. Deinde teneas philum super consimilem gradum videlicet super lineam circularem super quam gradus ille habet vel

haberet si esset ibidem [f. 38] suum contactum, circumducendo cauillam in summitate mali quousque nodulus recte fuerit super lineam hore duodecime. Et tunc capiendum est lumen solis versus eandem partem in qua parasti nodulum, ita vt lux appareat in foramine vel in linea transuersa alterius tabule; et nodulus in primo visu ostendet tibi horam vel hore particulam. Si longitudines dierum cognoscere volueris videlicet ab ortu solis in occasum, ponas philum super lineam, vel inter lineas ita equedistantem vt non obliquet eas; et habes orizontem. Et per orizontem horis cum particulis ex vtraque parte recte dupplicatis habebis diei ac noctis quantitatem vbicunque fueris in tota terra. Et si per mutacionem loci nodulus non attingat lineam suam in hora duodecima, ligetur cursor mali in maiori latitudine, videlicet remocius a centro nauicule, et si excedat, ponatur cursor in minori latitudine versus centrum, vbi incipiendum est latitudines computare per quinque et quinque, et postea per gradus secundum quod ibidem apparent. Item non assuescas mouere malum per partem eius superiorem, sed per inferiorem, ne nimio labore peioretur in axe. ℄ Quo die mensis sol intrat in signum.

Menses.	1	2	3	4	5	6	7	8	9	10	11	12
Dies.	11	10	12	12	13	13	15	15	15	15	14	13

Si volueris horam noctis inuenire oportet quod habeas in kalendario tuo cum predictis signis signa opposita. Et in quolibet signo nomen alicuius stelle notabilis in loco longitudinis sue fideliter scriptum cum gradibus sue latitudinis et hoc per gradus zodiaci, et [f. 38v] vtrum stella sit septentrionalis vel meridionalis. Et tunc agendum est cum stella sicut cum sole si esset ibidem, et sic habebis horam stelle. Et si gnadir solis sit in eadem longitudine cum stella, eadem est hora solis et stelle; quia sol et gnadir eius licet in diuersis emisperijs semper consimiles describunt horas. Si gnadir solis precedat in kalendario videas per quot dies computando .15. dies pro hora; et quociens inueneris .15. tociens addas horam vnam cum diebus remanentibus horis stelle, et habebis horam solis. Et si stella precedat gnadir solis, tociens minuas horam vnam cum diebus remanentibus de horis stelle. Et sic iterum habebis horam solis.

Note on the authorship

T. Allen is stated to have been the owner in 1622 of a MS. 8vo codex, now lost, which contained a treatise *De compositione navis, quadrantis et cylindre* by an otherwise unknown author, John Slape. Was he perhaps the author of the *Navicula*?

E. CATALOGUE OF THE LIBRARY OF WILLIAM REDE, BISHOP OF CHICHESTER, *d.* 1385

The books that belonged to William Rede, which still survive in Oxford, are of interest not only because they belonged to a man of science who was at the same time an ecclesiastical dignitary, but also because they illustrate the constitution of the yet earlier libraries of those who preceded him. To the works which he acquired by gift from his early tutor, Nicholas de Sandwych, or by purchase from the executors of Archbishop Islip and of Thomas Trillek, Bishop of Rochester, or by exchange with W. Lynham, he does not appear to have added many—at least if we may judge from those extant in Oxford. During his lifetime he is said to have given 25 books to Exeter College in 1374, perhaps including the *Sententiae* of P. Lombard given to Rede by Nicholas de Sandwych.[1]

By his will dated 1–3 Aug. 1382, and proved on 9 Nov. 1385 he bequeathed:

To the Bishop of Chichester 16 books
To Merton College 100 books, of which 36 codices are extant

New	50	,,	,,	11	,,	,,
Exeter	20	,,	,,	1	,,	,,
Queen's	10	,,	,,	0	,,	,,
Oriel	10	,,	,,	0	,,	,,
Balliol	10	,,	,,	2	,,	,,
Arundel	13	,,	,,	0	,,	,,

Ordering in all cases 'ut in librariis firmiter chatenentur'.

To Monasterium de Bello	1 book	
,, de Boxle	1 ,,	
Priory of Lewes	1 ,,	
,, Sele	1 ,,	
,, Calceto	1 ,,	
,, Michelham	1 ,,	
Monastery of Ponte Roberti	1 ,,	of sermons
,, Begham	1 ,,	,,
Priory of Tortyton	1 book	
,, Heryngham	1 ,,	
,, Boxgrave	1 ,,	
,, Schulbrede	1 ,,	
Monastery of Dureford	1 ,,	
Church of Otteham	Books	
Richard Pestour	1 missal and 1 portiforium	

Richard Pestour et scolaribus de genere meo 100 books.

[1] My friend Mr. P. S. Allen, the librarian of Merton College, has been kind enough to check this list with the MSS. in his charge.

When Bishop Rede's books were distributed among the various Colleges, a scribe and notary, Walterus Roberti, rector of Notehurst, who was an executor and received x marks under the will, wrote titles and notes of gift inside the covers of the books, and while asking for prayers for the soul of his benefactor did not forget to ask for one for himself for he 'diligenter insudavit' over the matter.

From W. Lynham, he obtained by exchange:

Anselm *Opera varia*	MS. Mert. 19.
S. Augustine *Opera varia*	
Aristotle *de Causis.* A commentary	Mert. 140.
Clemens papa *Ars fidei catholicae*	
S. Augustine *de spiritu et anima*	
John Damascenus *Mansur*	
S. Augustine *de vera innocentia*	
Richard de S. Victore *de potestate ligandi et solvendi*, etc.	
Thomas Aquinas *expositio*	
S. Augustine *de civitate Dei epitome*	
[Hugo de S. Victore] *Annotationes in Testamentum vetus*	

From the executors of Archbishop Islip, *d.* 1366, he purchased:

Seneca *Opuscula*	Mert. 297.
Cicero *de officiis, de paupertate, de senectute, de paradoxis*	
Chrysostom *Homiliae in S. Matth. evangelium*	New 306.

From the executors of John de Shepea, Bishop of Rochester:

Collectanea of John de Shepeya	Mert. 248.
Sermones Vasconici of John de Shepeya, i & iii	New 92.

From Thomas Trillek, Bishop of Rochester:

S. Johannis Evangelium et Ricardi de S. Victore comm. in Apocalypsin	New 55.
Concordantiae Bibliorum	,, 70.
Johannes de Schepeya *Sermones Vasconici*, ii	,, 92.
De modo poenitendi, etc.	,, 96.
Notes for sermons	,, 97.
T. Aquinas *Summa*, Pt. i, ii, iii	New 120, 121, 124.
Origen *Moralitates*	MS. Mert. 27.
Thomas Aquinas *Quaestiones*	,, 77.

Thomas Aquinas *de veritate catholica* MS. Mert. 78.
Gerard Bononiensis *Quaestiones* ,, 149.
Nicolas de Gorham *Postillae* MSS. Mert. 166, 168, 169, 170.
Hugo de S. Caro *Commentaries on the Apocalypse* Mert. 190.
Indexes to parts of the Bible, etc. ,, 197.
Sermones notabiles Mert. 237–239, 242.
Philip de Thaun *Bestiarium moralizatum*
Sententiae morales
Innocent III *de miseria humanae conditionis*
,, *decretales*
,, *de missa*
Kalendarium
and other works
} Mert. 249.
Nicolas de Byard *Distinctiones* Mert. 252.
Robert Grostete *on the Posterior Analytics and Physics*
Robert Grostete *de luce*
} Mert. 295.
Cicero *de officiis, de natura deorum, de fato*
Epitaphia Ciceronis
Orationes Philippicae
Palladius *opus agriculturae*
} Mert. 311.
A codex of *Historical Treatises*
Now in the Bodleian, MS. Digby 19.

From his tutor NICHOLAS DE SANDWYCH, Rede obtained some philosophical and theological works, and an interesting collection of scientific books:

Bradwardine *De causa Dei contra Pelagium et de Virtute causarum*
Th. de Bukyngham *Quaestiones*
} New Coll. 134.
Boethius *de consolatione philosophiae.* Commentary by Willelmus de Frumenti lege,[1] or Wethelay. New Coll. 264.
Peter de Riga *Aurora* Mert. 8.
S. Augustine *Opuscula*
S. Anselm *Meditatio*
Hugo de S. Victore *Commentary on Dionysius Areopagita, Caelestis Hierarchia*
Aegidius de Columna *de Sacramento corporis* Christi
De compositione chilindri
De compositione quadrantis, 'que composita fuit Oxonie'
Tractatus *de quadrante*, cum tabulis
Robert Grostete *de sphaera*
} Mert. 35.

[1] 'Frumenti lege', apparently a bad Latinization of Wheatley.

W. Ocham *de corpore Christi* } MS. Mert. 137.
Aegidius de Columna *opuscula*
Godefridus de Fontibus *Quodlibeta* } Mert. 138.
Thomas Sutton *Quaestiones*
Psalterium Davidis Mert. 208.
Simeon Burneston *Sermones*
" *de vocabulis praedicabilibus* } " 216.
Robert Grostete *de oculo morali*
Rhases *Almansor* trans. by Gerard of Cremona
" *Divisiones*
" *Antidotarius* } " 227.
" *de juncturis*
Avicenna *de naturis animalium*
" *de medicinis cordialibus*
Alex. Neckham? *Orthographia nominum hebreorum*
Alex. Neckham? *Repertorium vocabulorum Bibliae* } " 234.
Indices to various biblical, etc., works
Averroes *Commentarius super Aristotelis Physicorum* fourteenth cent., MS. Balliol 94.

A codex of the thirteenth century (MS. Balliol 285) containing the following works:

Moralium Dogmata philosophorum
Aristotle *de regimine principum* or *Secretum Secretorum*
Marbodus *de virtutibus lapidum* or *Lapidarius*
Sermo de xii lapidibus
De carne quorundam animalium
Tractatus quadrantis, quartae partis Astrolabii
beg. 'Scire debes, quod circulus solis'.
De efficacia medicinarum, quomodo ad humana corpora secundum potentiam planetarum et signorum effectum
beg. 'Inter astrologos est ardua'.

Kalendarium for the year 1239.
To which are added in another hand:

a. *Quaestiones nonnullae medicinales*
b. *Carta obligationis*, Milo Doget to Peter de Clif, rector of Nerny: dated Dublin 1289
c. *Carta* F[ulconis de Saunford] archbp. of Dublin to Peter de Clif of the church of Clunard: dated Suwerdes xvi kal. Iulii 1259
d. *Inspeximus* of ditto.

Magister Richard Anglicus *Micrologus*
De urinis

De chiromantia (French MS.)
Rhases *Liber ad Almansorem*
„ *de divisionibus aegritudinum*
„ *Antidotarium*
„ *Experimenta de doloribus juncturarum*
Galen *Experimentatio medicinalis*
Hippocrates *Liber praescientiae*, qui inventus est in sepulchro ejus in pixide eburnea
Hippocrates *de morte subitanea*
Onomasticon vocum Arabicarum
Tractatus *de effectibus qualitatum*
De conferentibus et nocentibus cerebro et aliis membris totius corporis
John de S. Paulo *de medicinis simplicibus* or *de virtutibus herbarum*
Richard [Anglicus?] *de laxativis*
Versus *de pluvia, de nive, aliisque meteorologicis*

Mag. Bartholomaeus *Practica*

a. Sententiae proverbiales
Containing the note 'Liber Willelmi Read, ex empto de bonis sibi datis per magistrum Nicholaum de Sandwyco.
b. Tabula contentorum
c. Aristotle de sanitate servanda
d. De quinque clavibus sapientiae
e. De sphaeris.

Arzachel *Astronomical tables*
Hermannus Contractus *de mensura Astrolabii*
Abulcacim *de Astrolabio.* Latin translation by John Hispalensis
Alchabit *Liber introductorius ad magisterium judiciorum astrorum*: trans. by J. Hispalensis
Alfraganus *de motibus coelestibus*
Arzachel *Canones astronomici*
De usu astrolabii
Albumasar *Flores*
De partibus latitudinis planetarum in signis xii
} MS. Mert. 259.

Aegidius [de Columna?] *Commentary on Aristotle de bona fortuna*
Commentary on Aristotle Meteororum, iv
Averroes *Theriaca*
} MS. Mert. 281.

Fernandus *Comment. on Aristotle Metaphysics* *Index* to some medical book Alexander [Aphrodisiensis] *Comment. on Aristotle Meteororum* Aristotle *de Physionomia* Albumasar *de magnis conjunctionibus* " *Introductorium in Astronomiam*	MS. Mert. 281.
Averroes *Comment. on various Aristotelian books* Avicenna, ditto	MS. Mert. 282.
Martianus Mineus Felix Capella *de nuptiis philologiae*	Mert. 291.
Tabula concordanciarum philosophiae extractae ex omnibus libris naturalibus Aristotelis et aliorum philosophorum	Mert. 294.
Gualterus Burlaeus *in Aristotelis Topicorum libros expositio*	Mert. 295.
Aegidius de Columna *Comment. on Aristotle de generatione et corruptione* Aegidius de Columna *Comment. on Aristotle Physics*	MS. Mert. 305.
Questiones. Now in the Bodleian.	MS. Digby 216.

Of Rede's other books we know of one containing *Tabulae* MS. Jesus 46.

And in the Bodleian is at least one other MS. given by Rede to Merton College, MS. Digby 176, a volume of supreme value, to which reference has already been made on p. 58.

In the British Museum Cotton MS. Julius B. III contains three historical works by Rede: *Chronica de papis* by Richard of Cluny to which Rede added lives from Honorius III to Gregory IX; *De Archiepiscopis Cantuariensibus ad Whittlesey*; *Chronica a Bruto usque ad 1367.*

F. NOTES ON CERTAIN BODLEIAN CODICES CONTAINING DESCRIPTIONS OR FIGURES OF ASTRONOMICAL INSTRUMENTS

MS. Ashmole 1522 — before 1350.

f. 72. Old Quadrant of John of Montpellier.
Celestial globe or Astrolabium sphericum of 1302.
Turket.
Semissis.

f. 122–32. New Quadrant of Profacius

MS. Digby 98. Written by a Merto ı man, perhaps Walter Brit — 1395.

f. 165. Quadrant (1244 type). $5\frac{1}{2}$ inches radius.

f. 76. Navicula $3\frac{3}{4}$ inches in width. 2 drawings scribbled over in red ink.

MS. Bodley 68 (S.C. 2142) — written *c.* 1400.

f. 48. Sinecal Quadrant.

MS. Digby 48. Rede's Tables, and Tables of Eclipses for 1433–62.

f. 15 b. Zodiac man 5 in. high.

f. 113. Planetary volvelle $3\frac{1}{2}$ in. diam. and circular dial for back of instrument.

f. 203. Volvelle $4\frac{3}{4}$ in. diam. (p. 240).

MS. Bodl. 472 (S. C. 2492). Written by Tristrandus of Louvain 1437.

f. 117. John of Montpellier's Old Quadrant $4\frac{3}{4}$ in. radius.

MS. Digby 17 — *c.* 1490.

f. 15–. Astrolabe $2\frac{1}{2}$ in. diam.

f. 158 b. Nocturnal.

f. 160. Profacius' New Quadrant.

f. 164. Construction of ditto $2\frac{1}{2}$ in. radius.

f. 164 b. Dial for back of ditto 4·3 in. diam.

MS. Savile 100. A book of cardboard instruments.

f. 2. A quadrant-shaped scale, dated 1552. See p. 175.

f. 2 v. Semicircular scale of $5\frac{1}{2}$ inches radius of the ÆQVATORIVM ECCLIPSIS SOLIS.
Above this is a TABELLA CONTINVATIONIS MEDIARVM ♂ & ♀.

Below is a TABVLA MEDIARVM CONIVNCTIONVM & ☌ ☽ GENERALIS, contained in three concentric arcs of Horae, Gradus[30] and Signa[12] and their subdivisions.

f. 3. Semicircle, 11½ inches in diameter, with rim divided into degrees 0 – 180 – 360, the quadrants marked 5 – 10 – 15 – 20 – 21 –, area ruled into squares 0 – 60, and 64 – 0 – 64 as in a sinecal quadrant.

f. 4. Circle divided into the 12 Signs.

'Huc accersendae sunt tabellae duae, quas mstrô eclipsis ☉ adiunximus propter chartae cōmoditatem. Vna mediarā ☌ & ☌ ☽. Altera continuationis earundem.

f. 4 v. Planispheric projection, like the rete of an astrolabe, with 49 stars marked.

f. 5. Horizontal projection of the Sphere, with 53 stars marked.

f. 5 v. Tabula loci solis in Zodiaco.

Aequatio solis 1516–1585.
1586–95 ⟨added in a later hand⟩.

f. 6. Printed Volvelles, which can be adjusted for eccentricities of orbits of planets. The printed papers are mounted on an astronomical MS. Made for years 1520, 1540, 1560, 1580, 1600.

f. 6 v.
f. 7. } A large printed Star map by I. H. C., dated 1532.

Dedication: *Inclyto senatui Coronensi D. D.*

f. 8. Planetary Volvelle or Equatorium of 10 inches in diameter. Described and figured on p. 243.

f. 8 b. A roundel with various signs.

At end: Two printed slips.

'Nomina stellarum fixarum arabica, necnon e regione latina.
Stellarum fixarum appellationes.
Circulorum ac Syderum quorundam synonyma.
Constellationum nomina ex Ausonio.
Basileae M. D. XXXIX.'

In cover: A recess for a quadrant, now lost.

G. NOTE ON DR. BARKHAM AND OUGHTRED'S CIRCLES OF PROPORTION AND DOUBLE HORIZONTAL DIAL, p. 140

While these pages were passing through the press, Mr. Stevenson of St. John's College informed me that he had just found a brass rule which may have been used with Oughtred's instrument. Its length, 18 inches, is equal to that of the diameter of the plate of the instrument. It is provided with fiducial edges on two sides and with scales like those of the rules of some astrolabes or planispheres; and it is fitted with dove-tailed base blocks for two sights or indices (?) that are not now extant.

It also appears, from a holograph letter of Sir Kenelm Digby in St. John's MS. No. 37 that he and the 'honoured and worthy Doctor Barckham att Lambeth', corresponded on matters astrological. Digby draws Barkham's attention to a case in which it was 'proved' that a learned astrologer, Mr. Welles of Deptford, by inspecting the horoscope of a certain Mr. V. Nabod of Erfurt (fl. 1527), was able to 'pronounce confidently that the owner of that scheme did assuredly kill himself with his owne sword', as was alleged to have been the case. The MS., which is nicely bound with KD monograms stamped on the back, was presented by Digby to Laud, in whose Library at Lambeth, Barkham may have studied it.

H. CARVINGS BY GRINLING GIBBONS OF NAVIGATIONAL INSTRUMENTS AT THE ADMIRALTY

A series of admirable carvings of seventeenth-century instruments forms part of the decorations over the mantelpiece in the Board Room at the Admiralty. I am obliged to Captain Creagh-Osborne for having drawn my attention to them, for they illustrate in a most perfect manner several instruments of which no surviving example is now known. I owe the photographs to the courtesy of Sir V. Baddeley. The series includes—

Globe.
Nocturnal.
Cross-staff.
Sea Astrolabe.
Telescope.
Sector.
Gunter's Quadrant.
Pair of Compasses.
Book of mathematical drawings.
Astronomical Ring Dial.
Rings, marked, '3, 6, 12'.
Davis's Back Staff.

G. GIBBONS' CARVING OF NAVIGATIONAL INSTRUMENTS
GLOBE. TELESCOPE. UNIVERSAL RING DIAL. RINGS.
DAVIS' BACK-STAFF. NOCTURNAL. SEA ASTROLABE.

G. GIBBONS' CARVING OF NAVIGATIONAL INSTRUMENTS

CROSS-STAFF. SECTOR.

GUNTER'S QUADRANT.

I. DOCUMENTS RELATING TO WREN

The Visit of M. de Monconys to Wren in Oxford in June 1663

Owing to a slight alteration in the spelling of the name, Monconys' contemporary account of his visit to Wren appears to have escaped notice. I am indebted to my friend Mr. F. Madan for having drawn my attention to it.

[11 Juin 1663]

Outre le College [i.e. All Souls] que i'allois voir par curiosité comme tous les autres, i'y allay encore plus pour voir M. Renes grand Mathematicien quoy que petit de corps, mais des plus ciuils & des plus ouuerts que i'aye trouuez en Angleterre: car quoy qu'il ne veüille pas que ses pensées soient diuulguées,

Machines de M. Renes.

Il ne laissa pas de me dire fort librement celle de son Horologe[1] du temps, qui fait mouuoir vne regle, sur laquelle est attaché vn rayon qui marque sur des cercles concentriques qui correspondent aux heures, tous les changements des vents, qu'vne Girouëtte indique, en les faisant tourner, & de mesme les pluyes, la gresse, & la neige par des vases attachez à cette roüe, qui passent à châque heure sous vn entonnoir, dans lequel il peut pleuuoir, neger, ou gresser; & le chaud & le froid par vn Thermometre qui fait hausser, ou baisser vne tablette, contre laquelle vn crayon de la regle susmentionnée allongée autant qu'il faut pour cét effet, marque en trauers les heures, comme la table marque en hauteur les changements, dont la figure suiuante est vn grossier dessein.

Il me dit aussi sa pensée pour faire vn fourneau comme celuy de M. Keffer, sçauoir qu'il y ait deuant le Registre vn Vase, qui soit moitié dans le fourneau & moitié dehors, & qui soit plein d'argent-vif; lequel se haussant lors que l'air de la cornue qui est sur les cendres, le presse, il bouche le registre; car la muraille du forneau est comme vn diaphragme qui diuise le vaisseau du vif-argent en deux, comme cette figure en fera souuenir.

Le 12. [Juin] ie fus voir M. Renes, qui me dit

La maniere d'vn Thermometre[2] auec vn tambour, autour duquel il y a vn canal de verre, & dans ce canal vn trou qui communique dans le tambour, & vn autre qui communique, ou reçoit l'air ambiant; puis mettant de l'eau dans ce canal, elle fait tourner le tambour qui est suspendu par son centre, si bien que l'air qui est dans le tambour se rarefiant, sort par le trou du canal, & presse

[1] See vol. i, p. 318.

[2] See vol. i, p. 263.

l'eau, laquelle changeant de situation, en fait changer à la roüe, comme cette figure le peut faire voir grossierement. Et ce pourroit bien estre la machine de Drebel du flux, & du reflux, ou du mouuement perpetuel.

Il me dit aussi la maniere de connoistre le sec, & l'humide : car le sec n'estant qu'vne priuation, ou diminution de l'humide, il suffit d'obseruer la quantité de l'humidité : ainsi mettant vn grandissime, & large entonnoir de verre, dont le bec soit tres-estroit dans vne caue, ou lieu fort humide, & ombragé, & hors de l'iniure du vent, proche pourtant d'vne fenestre, & suspendu au plancher, en sorte qu'il n'y ait pas deux trauers de doigt entre l'entonnoir, & le toit ou voute ; car pour lors à proportion qu'il y aura de l'humidité dans l'air, elle se condensera en eau, & distillera goutte à goutte par le bec de l'entonnoir dans vne balance fort ingenieuse, pour marquer tres-exactement les poids de chaque chose. Elle est faite en sorte que la balance, ou le bras, est fixe sur son axe, & ne chancelle point, mais son axe estant suspendu par vn anneau, & la balance demeurant paralelle à l'Horizon, quand on charge tant soit peu vn bassinet, cette balance s'incline tousiours de plus en plus ; & il y a vn fil auec vn poids au bout, qui tombe perpendiculairement de l'anneau qui tient l'axe, lequel gardant tousiours sa perpendicularité passe par diuerses marques du bras qui s'incline, & montre ainsi la difference iuste des poids, comme cette figure fait voir grossierement. En chemin i'achettay pour vn chelin le liure *De Tachygraphia.* M. Vvreine me dit qu'il croyoit que l'esprit de sel estoit plus propre dans les Thermometres que celuy de vin.

Autres curiositez de M. Renes.

Monconys, *Voyage d'Angleterre,* 1666, pp. 53–5.

An Appreciation of Wren in 1667

Nunc *Animae* veniunt *Omnes,* generosa propago.
Hic evectus humo sublimis acumine mentis,
Aerias tranare vias, & sidera solers,
Non audita priùs reserat miracula Rennus.
Dumque suum, sedis paritèr caput inserit Astris.
Quod si mens intra pectus Divina vocatur,
Et meruit tantas animato è corpore, laudes,
Quantus erit, qui sic *Animas* animaverit *Omnes.*

F. V. [Francis Vernon] Ex Aede Christi,
Oxonium Poema, 1667.

Wren's Inventions exhibited at Wadham College

A CATALOGUE *of New* Theories, Inventions, Experiments, *and* Mechanick Improvements, *exhibited by Mr.* Wren, *at the first Assemblies at* WADHAM-COLLEGE *in* Oxford, *for Advancement of Natural and Experimental Knowledge, called then the* New Philosophy; *Some of which, on the Return of the publick Tranquillity, were improved and perfected, and with other useful* Discoveries, *communicated to the* Royal-Society.

PICTURE of the Pleiades.
Hypothesis of ♄, in Solid.
Hypothesis of the Moon's Libration, in Solid.
Illumination of the ☽ and Planets, in a dark Room.
A New Projection Goniscope.
New facile exact Ways of Observation.
To find whether the Earth moves.
The Weather-Wheel.
The *Libra Expansionis Aëris.*
Weather-Clock.
Perpetual Motion, or Weather-Wheel and Weather-Clock compounded.
The Ballance, to weigh without Weights.
Strainer of the Breath, to make the same Air serve in Respiration.
Artificial Eye, with the Humours truly and dioptically made.
The like Eye made with one Humour only.
To write in the Dark.
To write double by an Instrument.
A Scenographical Instrument, to survey at one Station.
A Perspective Box, to survey with it.
Several new Ways of graving and etching.
Many curious and new Ways of turning.
To weave many Ribbons at once with only turning a Wheel.
Divers Improvements in the Art of Husbandry.
Divers new Engines for raising of Water.
A Pavement harder, fairer, and cheaper than Marble.
To grind Glasses.
A Way of Imbroidery for Beds, Hangings, cheap and fair.
New Ways of Printing.
Pneumatick Engines.

New Designs tending to Strength, Convenience, and Beauty in Building.

Many new Designs in Sciography.

Divers new Musical Instruments.

A Speaking Organ, articulating Sounds.

New Ways of Sailing.

The best Ways for reckoning Time, Way, Longitude, and observing at Sea.

Probable Ways for making fresh Water at Sea.

Fabrick for a Vessel for War.

To build in the Sea, Forts, Moles, *&c.*

Inventions for better making and fortifying Havens, for clearing Sands, and to sound at Sea.

To stay long under Water.

Ways of submarine Navigation.

Easier Ways of Whale-fishing.

New offensive, and defensive Engines.

Secure and speedier Ways of attacking Forts than by Approaches and Galleries.

New Ways of Intelligence, new Cyphers.

Some Inventions in Fortification.

To pierce a Rock in Mineing.

To purge or vomit, or alter the Mass by Injection into the Blood, by Plaisters, by various dressing a Fontanell.

Some Anatomical Experiments.

To Measure the Basis and Height of a Mountain, only by journeying over it.

To Measure the straight Distance, by travelling the winding Way.

A Compass to play in a Coach, or the Hand of a Rider.

To perfect Coaches for Ease, Strength and Lightness, *&c.*

Parentalia, pp. 198-9.

Letter of Sir Christopher Wren

On Bishop Fell's proposal to use Tom Tower at Christ Church as an Astronomical Observatory

My Lord

As farre as I can perceiue by discourse with Mr Kempster[1] you haue hitherto proceeded very well in your Building

[1] Kempster was a builder employed to carry out Wren's designs both at Christ Church and in London.

& I hope I shall haue noe reason to beleiue otherwise when I see it and I should be glad you would proceed upon the first thoughtes. Yet I doe not reject your L^ps proposition of making it into an Observatory, & I was willing first to get rid of severall businesses that incombred me at once the last weeke that I might at leasure consider of this change for a Change it will be of the whole designe; for the Loft for the Bell aboue the ringing loft must be higher considerably & with large Windowes & still I doubt the Bell will be somwhat lowe to be well heard; then the octogonall Tower must be flat on the Top with a levell Ballaster (for pinnacles will doe injury) the windowes also must be only wooden shutters without Mullions or barres, these things considered it will necessarily fall short of the beauty of the other way, for having begun in the Gothick manner wee must conclude aboue with flats & such proportions as will not be well reconcilable to the Gothick manner wch spires upward & the pyramidall formes are essentiall to it, & this proposition had been much better effected had not the parts formerly built diverted us from beginning after the better formes of Architecture, & I feare wee shall make an unhandsome medly this way. Giue me leaue to adde, that such a Roome as this will be when built, is noe way necessary for Observations, as now they are managed. Were I to set up the Trade again I was once well acquainted with, & I thinke the world doth or may justly own some improuements of it to me, I should require nothing else but these things. First a large murall Quadrant fixt to a wall trewly built in the meridian, & this is best in an open Court or Garden, 2dly a pole to rayse large Telescopes & manage them, and the like place is properest for this also. 3dly A Quadrant to take distances fixt to a Foot soe as it may turne to all sort of plains, this having Telescope sightes & many nice Joynts & Screwes must be housed for its better preservation, but the best house will be a litle house of boardes about 12 foot square & 7 foot high & noe other roofe but what may be taken quite off when the Instrument is used, as you draw off the sliding lid of a box, or upon hinges as you open the Cover of a Trunke, & this will be as well don in a Garden as the top of a Tower, for wee valewe noe observations made neer the Horizon. Wee built indeed an Observatory at Greenwich not unlike what your Tower will proue, it was for the Observators habitation & a litle for pompe; It is the instruments in the Court after the manner I haue described wch are used, the roome keepes the Clocks & the Instruments that are layd by. After I haue freely told y^r L^p my thoughts I must confesse the last line of Y^r L^ps

Letter *That making this a part of our designe may probably advantage contributions* is that wch mooues me a litle, & if Your Lp continue in these thoughtes, wee will begin anew and alter what remaines the best wee can to this purpose. Begging Yr Lps blessing I remaine

Your Lps obedient humble servant

Whitehall
Dec. 3d 1681.

Chr. Wren.

I cannot but adde this Line that supposing all the necessary instruments provided for an observatory (& I dare undertake for the Charge of 300lb or 400lb at most to provide more usefull and accurate instruments then I find were ever yet made) I will then for lesse charge then a pidgeon house provide all the housing necessary.

[*Endorsed on back*]
To the Rt Reverend
Father in God
John Lord Bishop of Oxford
in Oxford.

[*In different hand*]
Sr Chr. Wren to Bp
Fell abt ye Tower.

This letter has been recently printed with valuable comments by Wren's successor in the Savilian Chair, my friend Prof. H. H. Turner, by W. D. Caröe in his *Tom Tower*, 25 Feb. 1923.

J. DOCUMENTS RELATING TO THE RADCLIFFE OBSERVATORY

Draft of a Letter written by Hornsby, c. 1773

Sir

You have been pleased to express your approbation of what I inserted in the Phil Transactions on the motion of Arcturus &c in a manner so highly flattering to me that I cannot avoid taking the first opportunity of making you my most grateful acknowledgmts. & at the same [time] declaring to you that I consider myself amply recompensed by so valuable a testimony for the labour of so many Calculations. It was matter of surprise to me that when so many Persons had mentioned that that star had a motion, that no one should endeavour to ascertain its Quantity. And as Messrs. Cassini & le Monnier had often compared the Altitude of the Centers of the Sun with this Star which I found to be a

variable instead of a fixt Point, I could not help endeavouring to determine from observation the Question that the Obliquity is at this time diminishing, & deduce the same Conclusions a posteriori, which Mr. Maclaurin, Mr. Euler & M. de la Lande had drawn a priori. I hope to send before the End of the Year to the R. S. a supplement to this Paper, in which I hope to be able to ascertain the Quantity of the Decrease since 1690. The Star η Pleiadum describes nearly the same Parallel with the Center of the Sun at the Summer Solstice. This Star as I can prove by observation from its position with the neighbouring Stars in 1690 & at present is a Fixt Point. It will therefore give me the exact Error of Mr. Flamsteeds Instrument; & consequently the Quantity of the Decrease since his Time. I have not yet had time to draw up the Paper, & to make the Calculations so fully as I propose: otherwise I would send you the result. But I will take the liberty to send you an Extract at the time that I send the Paper to the Society. I propose also in the course of the Summer to endeavour to determine the Quantity of the Motion of Sirius & Procyon, both which I find to move W & S. The former has a Motion Southward of about $1\frac{1}{2}''$, & the latter of nearly $1''$ in a Year independent of any known Motion. I hope also to shew that the Star γ Aquilae has not moved, while α & β both have changed their situation, contrary to what Mr. Cassini asserts in his Paper on that Subject in the Mem. for 1738.

Hitherto I have been observing with small Instruments purchased indeed at an Expense which I could not well bear, but made by Mr. Bird. I have the Prospect thro the Generosity of the Trustees to Dr. Radcliffes Will to be able to verify these Conclusions by larger and better Instruments. Two Quadrants of 8 f. rad. with achromatic Glasses, a Transit Instrument of 8 feet with an achromatic Object Glass of a very large aperture, & a Zenith Sector of 12 feet are actually finished. The Rooms for their Reception will be completed by the middle of next Month, & about the beginning of October I hope Mr. Bird will be able to come here to put them up. I shall hope in the course of the Winter to be able to adjust them. The Equatorial Sector is not yet made, but the detached Building which is to contain [it] is nearly finished. It is well calculated for the purpose, & is built upon the Suggestion of the Bp. of Chester after the Temple of Romulus & Remus.

When these Instruments are once adjusted, if you sh^d. wish to see any Observations I may make, I shall esteem myself highly distinguished if you will be pleased to permit

me to communicate them. And as you have condescended to begin a correspondence with me, You will not I hope take it amiss If I presume to ask you to honour me with a continuance of it. [*Unsigned.*]

Dollond's Bill for Telescopes, 1774

For the observatory at Oxford.

1774	By P. & J. Dollond.	£	s.	d.
Sept. 3	a 3-feet achromatic Telescope with triple object-glass, brass tube, a strong Stand with brass polar axis and the improved object-glass micrometer –	68	5	–
	an Helioscope to Do. – – –	2	12	6
	a machine for limitting the aperture of the Telescope in observing Jupiter's Satellites – – – – –	4	14	6
	Packing Cases – – – –	1	7	–
Decr. 31	a 10½ feet achromatic Telescope with double object glass, square mahogany tube, five eye tubes adjusted with rack-work and pinion, dark glasses and smoaked glass frame applied to all the eye tubes, a neat mahogany Stand made with a weight to balance the Telescope and a small Stand with adjusting screws to support and move the eye end of the telescope – –	50	0	–
	Altering a Graham's micrometer, making two new eye tubes and other brass tubes for applying it to the 10½ feet Telescope – – – – –	5	15	6
	A single object-glass of the same aperture and focal length as the achromatic object glass, fixed in a brass Cell and applied to the telescope – – –	2	2	–
	A neat deal Box for holding the Eye tubes and object glass belonging to the telescope and micrometer – –	–	12	–
	A copper funnel for a Plueviometer –	2	12	6
	A very large and Strong packing Case for the Stand and two others for telescope and Boxes – – – –	2	15	–
		£140	16	–

G. GIBBONS' CARVING OF NAVIGATIONAL INSTRUMENTS

BACK-STAFF. SECTOR.

TIDE COMPUTOR.

From photographs taken for Sir V. Baddeley

G. GIBBONS' CARVING OF NAVIGATIONAL INSTRUMENTS

GLOBE. TELESCOPE. COMPASSES. CROSS-STAFF.

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